The New All-Metal Flying Boat

THE recent launching of the Iris III., which took place at Brough, on the Humber, was an event of considerable significance, and indicates one direction, at least, in which progress is being made. The Iris III. represents the largest and fastest of all metal flying boats built in this country, and embodies developments that are the result of intensive research. The difficult task of launching a boat of this type was accomplished with remarkable ease, considering that it has a weight of over 14 tons and an immense spread of wings. True, the weather was favourable, there being hardly sufficient breeze to create a ripple on the water, but, even so, it is not always that arrangements made for a launch are carried out so successfully and with the same precision as in the case of the Iris III. Very few people were present, due, no doubt, to a considerable degree of secrecy that had been preserved from the commencement of its construction. Drawn from its hanger to a slipway by a traction-engine, the engines of the new craft were started while about fifty men steadied the slowly moving boat until it entered the water, when, moving steadily under its own power towards mid-stream, the roar of the engines increased as they were accelerated, and she rose from the water most gracefully. After circling about, the flying boat made an excellent landing, and, after a very brief stay, started on her maiden voyage to Felixstowe.

This brief description of the launching ceremony gives little indication of the phenomenal developments that have been made in aircraft. Much credit is due to the indomitable spirit of pilots, who, by their resourcefulness, skill, and courage have been largely instrumental in enlarging the possibilities of this form of transport. Recent developments have shown, however, that the substantial advance in the development of alloys is undoubtedly reflected in the progress. The standard of production of the alloys involved, from the standpoint of both reliability and special characteristics, have been enormously advanced as a result of recent research. The engineer and designer, too, have made considerable progress in the knowledge of the stresses imposed upon mechanical structures, and of the means employed to carry them successfully. Not least of the factors that have assisted the progress of aircraft construction at such a phenomenal rate is the increased knowledge of the machine-shop personnel in regard to the machining and assembling of parts.

The Iris III. is the latest development of the well-known Iris type of reconnaissance and coastal patrol flying boat, of which the first was produced in 1926. Since that date the Iris type has remained the largest and fastest flying boat of its class, and has maintained a high reputation for seaworthiness, manœuvrability, and performance. Although this new flying boat retains the chief characteristics of its prototypes, it possesses, in addition, a number of improved and advanced features, as a result of the experience gained during three years of arduous active service, developments in metallurgical research, and advances made in internal combustion engines. The first Iris was of composite construction, with wooden hull and composite superstructure. In 1927 a metal hull of similar but improved lines of duralumin construction, with stainless steel main fittings, and incorporating the additional feature of a tail defence station behind the centre rudder, was constructed and fitted with the original superstructure of Iris I. The all-metal structure of the hull, which at that time represented the most modern development of duralumin construction, has distinct advantages over wooden construction, both as regards improved design characteristics and actual service efficiency. In comparison, the actual structural weight of the metal hull involves a saving of 400 lb., and by eliminating the water soakage of wooden construction saves a further 600 lb., thereby allowing a total of approximately 1,000 lb. available for additional useful load.

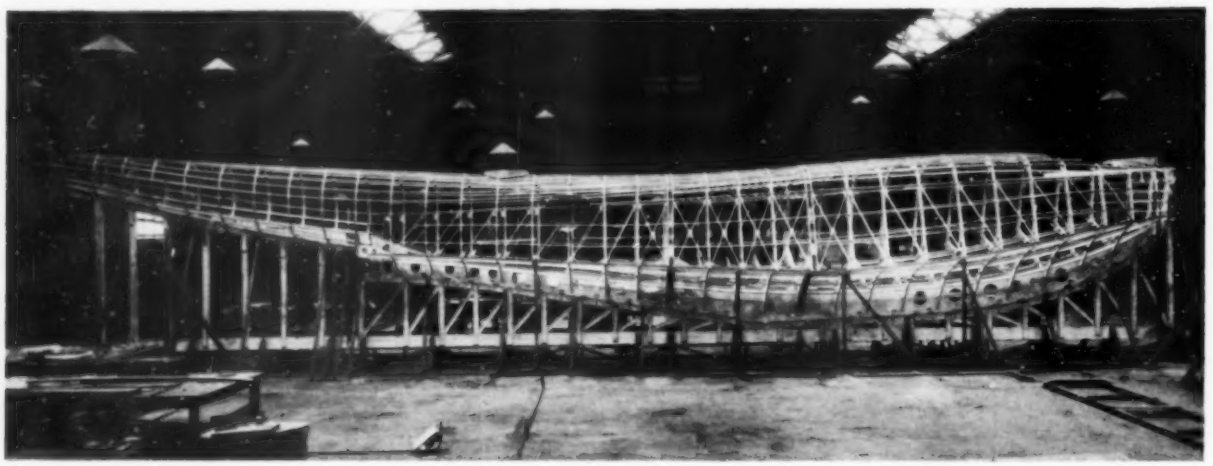
In view of the fact that duralumin plays so important a part in the new flying boat, the characteristics of this light alloy are worthy of consideration. Duralumin is an aluminium alloy, which is approximately one-third the weight of steel. It has been produced after years of systematic endeavour to meet the demand for a metal which, while being as light as aluminium, will have the strength of steel, yet without the disadvantages characteristic of aluminium in its pure state. The approximate composition of the finished alloy may be taken to consist of: Copper, 3·5 to 4%; magnesium, 0·5 to 1%; manganese, 0·5 to 0·75%; silicon and iron under 0·6%, and the remainder aluminium. This alloy is available in various forms and sections, and is graded according to the purpose for which it is desired. It is supplied as sheets, strips, tubes, angles, stampings, and forgings, but there is no appreciable advantage in making use of the alloy for castings, as its characteristics are dependent upon working and heat-treatment. When the work involves forging or a hot pressing, the metal is uniformly heated to a temperature

of from 400° to 420° C. This can be performed by heating the material in a salt bath consisting of an iron or steel container partly filled with a mixture of potassium and sodium nitrates, the heat being applied externally. The use of such a bath is not always practicable; in such cases a closed muffle furnace will answer the purpose, but it is necessary to exercise care, to prevent the burning of the metal during the annealing operation.

For pressing, drawing, or bending work on the alloy in the finished state, such as sheets, bars, and sections, it may be necessary to anneal, and this should be done at a temperature of approximately 360° C., but should not exceed 400° C. and the metal quenched in water. When several operations are involved annealing will be necessary between each operation, and the work should be done directly after quenching, or the metal may become too hard. The heated and subsequently quenched alloy hardens gradually during the first four days, after which no further hardening takes place. It is this annealing process and final age hardening that gives the alloy remarkable strength, which varies from 24 to 28 tons per square inch in tensile, according to size, enabling it to compare with mild steel in this respect. Among its characteristics is the high resistance it offers to corrosion by sea-water, a property of primary importance in the all-metal flying boat. In addition, duralumin is non-magnetic, withstands atmospheric influences, and is only slightly affected by numerous chemicals, which so readily corrode many other metals and alloys. Reference has already been made to the actual saving in weight over a wooden construction, but, in addition, the use of this metal in the construction of the hull increases the space inside the hull available for accommodation, and enables the formation of unrestricted walkways throughout the interior. In operation the metal hull forms a more serviceable and economical unit, particularly as regards maintenance, repairs, and replacements. The strength of the structure and the seaworthiness of the hull enable it to ride out the heaviest weather in which flying operations would be considered reasonably safe.

In design the metal hull is a rigid type of construction, consisting of comparatively widely spaced transverse frames of full section, including the planing bottom structure integral with the hull and longitudinal stringers. This longitudinal system is varied on the sides of the hull by the introduction of diagonal stiffeners between the frames, the whole forming an "N" girder system which gives an improved transmission of shear loads. The frames are attached to a centre keelson, which is continuous throughout the length of the hull. For additional rigidity all constructional members are directly attached to the duralumin shell and riveted with duralumin rivets. Although the hull consists primarily of duralumin, special attachment fittings for the main planes and tail planes are of stainless steel. This stainless steel is noted for its resistance to corrosion and in possessing high tensile strength. A typical analysis of a stainless or chrome steel contains 10·44% chromium, 0·24% carbon, 0·36% manganese, 0·3% vanadium, 0·013% sulphur, 0·02% phosphorus. This alloy is quenched at from 980° to 1,000° C., and drawn at 440° C. Other alloys to resist corrosion are frequently used, known as nickel-chrome steel alloys. Two different alloys of this type are commonly used.

A typical analysis of one consists of 3·5% nickel, 1·5% chromium, 0·35% carbon, 0·55% manganese, 0·04% sulphur, and 0·04% phosphorus; while the other alloy contains 1·25% nickel and 0·65% chromium, the other constituents being practically unchanged. There can be no doubt that the resistance to corrosion is of primary importance in the development of aircraft materials.



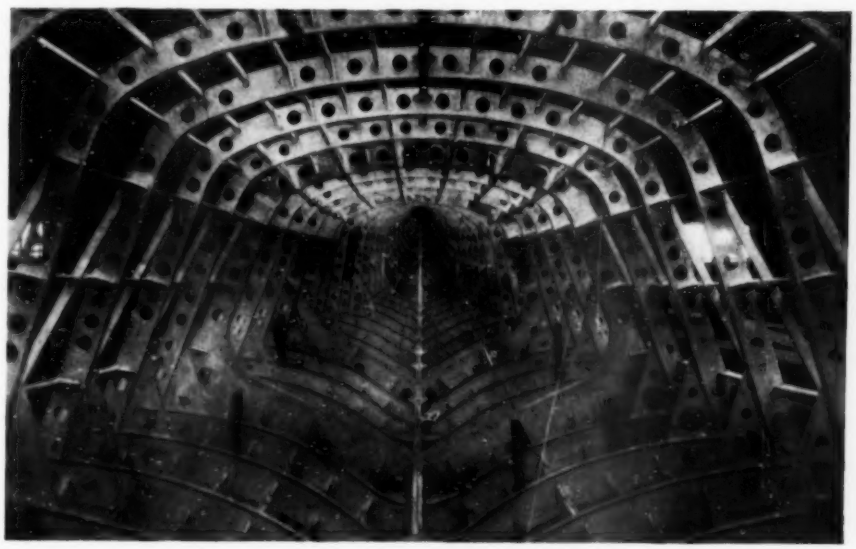
The hull has two steps, a deep fore foot, and is well flared to keep down spray; on actual service it gives a highly satisfactory performance as regards clean running, rapid and easy take-off, and steady running on the water on alighting. Its aerodynamic efficiency also reduces resistance to a minimum.

This development in the use of an all-metal hull largely represents the progress in the Iris II., which has accomplished some outstanding flights during a very active career, and is still in service. It is interesting to recall that the Iris II. acted as flag-ship during the Baltic cruise of British flying boats in 1927, and in spite of persistently adverse weather conditions throughout the voyage, the boat performed with remarkable efficiency, and a further indication of its reliability was exhibited in 1928, when it successfully carried Sir Philip Sassoon, Under-Secretary of State for Air at that time, over the greater part of his 17,000 miles tour to India and back.

In common with the Iris I. and II., the Iris III. is a large three-engine boat, with bi-plane wings and tail unit. The duralumin hull is constructed on similar lines to the earlier types, and an idea of its size may be gathered from the fact that had the boat been intended for passenger service there would be ample accommodation for twenty-eight persons. A new super-structure of all-metal construction has been fitted, and, in addition, the main planes and tail unit are almost entirely of duralumin. Three Rolls-Royce "Condor" engines, each capable of developing 675 h.p., at normal revolutions per minute, are installed between the wings and are mounted on special duralumin cradles, which are supported by simple steel-cube structures. Continued development of this engine has brought it to a point of refinement equal to any of its class in Europe. The "Condor" engine is of the 12-cylinder water-cooled "Vee" type, with the cylinder banks placed at an angle of 60°, and with overhead valves. The engine is a fabricated

structure, the cylinders being of carbon steel, apart from which the new alloy steels play an important part, varying in characteristics according to the varying stresses the details in the construction are required to withstand. Although the single engine may be said to have distinct advantages over the multi-engined installations, primarily due to the fact that a single large engine unit can be made heavier per unit of power output, thereby increasing its reliability, yet, it is claimed, after much experimental work, that the installation of three engines in the Iris III. renders the flying boat almost immune from forced descent. Sufficient power is generated by two engines to enable the boat to take off from the water, and, with only the two in action, climbing and turning in either direction are under complete control. In the event of the failure of more than one engine—considered to be highly improbable—flight can be continued, the machine being capable of covering a long distance with a gradual loss of height. The cradle upon which each engine unit is mounted is readily detachable from its steel tubular supporting structure, and, which still carrying the engine, can be conveniently transported to hangar or workshop and set on the floor, or on a bench, to form an accessible support for the engine in order to facilitate repairs and overhauls. Included in each unit are the cooling and oil systems and starting gear. The cooling system is by water, it being circulated by a pump operated by the engine, and includes a water-tank radiator, and radiator shutters. The oil system is also circulated by an engine pump, through a tank, a special type of cooler, and filters. The starting gear consists of a shaft to which handles are fitted, self-starting magneto, and the necessary controls, operating the clutch, and decompressor on the engine. In addition, each engine is fitted with quickly detachable aluminium cowling, which allows complete accessibility to the engine and oil and water systems. The engine controls are operated by pull-and-push rods and levers throughout, from the pilots' cock-pit. The engine control quadrant is placed between the two seats in the pilot's cock-pit, so as to be operated from either seat. The quadrant incorporates a throttle and altitude control lever for each engine, and also a master lever which operates all three together; this arrangement permits of easy adjustment and synchronisation of the three engines, and also provides for the simultaneous control of all three, an advantage in an emergency.

There are five petrol tanks of aggregate capacity of four tons, and the normal range of a thousand miles can be increased to 1,500 miles. The tanks are provided with adequate baffles for strength and to prevent surge. A number of filters are provided in the cistern to ensure the cleanliness of the petrol throughout the cistern to the engines. An important feature of the petrol system is that no petrol is carried inside or lead through the hull.



Airlerons are fitted to both top and bottom planes, two being on each side, which are linked together by stream-line wires and compensating cable between the top airlerons complete the circuit. The control cables of the airlerons are carried back inside the hull, as are the elevator and rudder control cables. All the controls are light and well matched, so that the pilot is not unduly fatigued during long periods of flight; ease of control also adds to the safety and efficiency of operation.

As a military boat, the Iris III. will be used for coastal patrol work, and adequate accommodation is provided for her crew of five, each member being stationed with every facility for efficient attention to his duties.

THE DEVELOPMENT *of* MATERIALS FOR AIRCRAFT PURPOSES.

By Dr. W. ROSENHAIN, F.R.S.

In a lecture delivered before the Royal Aeronautical Society on December 12, Dr. Rosenhain surveyed the whole field of materials used for aircraft construction regarding the properties required of the materials. He made the survey with a view to studying the general trend of development on broad lines, and in order to estimate the present direction and future tendencies of such developments.

The properties of materials which are of primary interest for aircraft purposes are the following :—Ratio of strength to weight, stiffness, resistance to fatigue, resistance to wear, to corrosion and to high temperatures, and facility of fabrication by jointing and forming. In regard to the strength-weight ratio, Dr. Rosenhain pointed out that tensile strength cannot be regarded as a measure of usefulness for many aircraft purposes, where resistance to fatigue, and stiffness as well as resistance to corrosion, are at least as important. Special importance attaches to the connection between corrosion resistance and fatigue, which has been discovered in recent years, and the whole question of corrosion resistance and means of protection from corrosion is regarded as of primary importance in the future development of aircraft materials. In regard to stiffness, the importance of a high elastic modulas was considered, together with the possibility of future improvements in alloys, both steel and non-ferrous, in this direction.

The ultra-light alloys of magnesium were considered, with particular reference to their protection from corrosion, their elastic modulus, and their strength-weight ration in relation to their ductility. Beryllium and its alloy were considered, and reference made to the present limitations of these materials. Finally, the question of the behaviour of materials during fabrication were considered with special reference to welding. Consideration of the advantages and disadvantages of this process leads to the suggestion that alloys particularly suited for welding may be developed in the future, which can overcome some of the difficulties and disadvantages at present inherent in this valuable process of jointing.

Principles and Uses of Wire Rope

Part II.

By WALTER A. SCOBLE, D.Sc., M.I.MECH.E.

Head of Engineering Department, Woolwich Polytechnic.

Treatment of steel, process of drawing into wire, and subsequent tests to which it is submitted.

AFTER steel has been treated with acid, either at this stage or in connection with galvanising, it is liable to show brittleness. It is now generally agreed that the brittleness is caused by occluded hydrogen generated by the action of the acid on the steel, and that the occlusion and consequently the brittleness increases with the time of immersion of the steel in, and also with higher temperature of, the acid. A balance is struck here because an increase of the acid temperature reduces the time required to clean the wire. The brittleness disappears with the diffusion of the hydrogen, a matter of time which is lessened by a rise of temperature, but the operation of ridding the steel of hydrogen is combined with another. It is necessary to have a coating on hard wire for the drawing operation, which coating is usually hydrated iron oxide formed thus. After pickling, the wire is washed to remove all traces of the acid, then it is kept moist during a period sufficient for the oxide to be formed. The wire is also dipped in lime and baked to dry the lime, but also to remove the last traces of hydrogen.

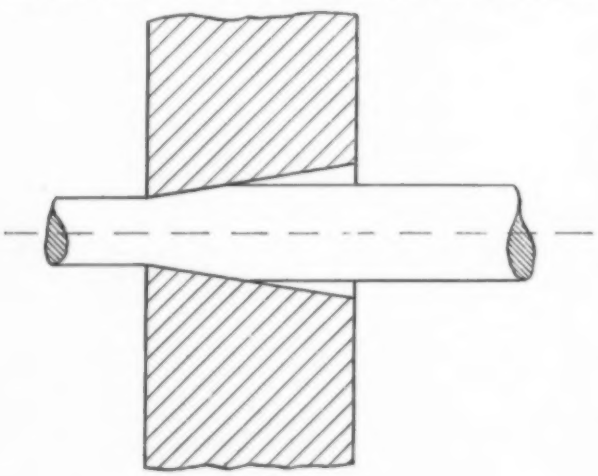


Fig. 1.

It should be made clear at this stage that it is possible to give only a general outline of the subject of wire drawing, with the hope that the factors which influence the properties of the finished wire will be indicated.

Wire is reduced in diameter by pulling it through a die of the shape illustrated in Fig. 1. The die is a tapered hole in a block of chilled iron or of hard cast steel, the latter being favoured in this country. The diameter of the wire after the pass is that of the small end of the die. The hole wears large in time, so the die is made of a metal with sufficient malleability to allow the hole to be closed by hammering, after which it is reamered to the correct size. The passage of the steel through the die should be a uniform flow across the wire section, the surface and core passing without one lagging behind the other.

When a steel specimen is pulled, the stress appears to be more intense on the centre line, or, at least, after yield the stretch is greater at the centre than at the outside of the metal. This is shown particularly well when thin plate specimens are broken in tension, and the test can often be stopped when the condition is as shown in Fig. 2, the plate having parted at the centre with the edges still holding. This unequal stretch must be avoided in wire drawing, the means employed being the intense lateral pressure exerted at the wire surface by the gradually tapered portion of the die.

The wire is pointed to enter the die—by rolling, heating and hammering, or filing, whichever is best suited to its size. The reduced end of the wire is passed through the die and gripped by tongs and pulled until a sufficient length has passed the die to allow the end of the wire to be attached to a drum. The drum is power-driven, and by its rotation pulls the wire for the draw. The wire coils on the surface of the drum. The drum has its axis vertical, and tapers with the smaller diameter at the top. As the wire coils on at the bottom, the early layers slide upwards on to a smaller diameter, so the turns do not bind and the complete coil can be removed with ease. The lateral pressure of the die on the wire is increased, for a given pull, by a reduction of the angle of the taper, and the frictional resistance to the passage through the die is correspondingly increased. It is clear that the pull on the wire must be appreciably less than the breaking strength of the smaller portion, consequently, when the co-efficient of friction between the wire and the die is large, the lateral pressure must be reduced by increasing the angle of the taper of the hole, but when the friction is small a long taper and bearing are better.

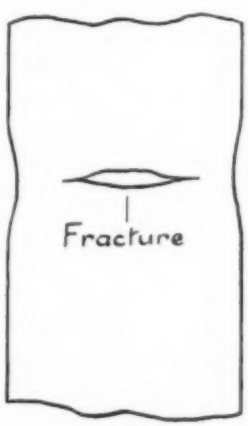


Fig. 2.

Machines are now available in which wire is drawn through several holes in series, which means that the wire suffers three or four reductions in diameter during one passage through the machine.

It is well known that friction between similar metals is considerable, and this applies when steel wire is drawn through a steel die. Further, high friction and speed of drawing lead to much heat being generated, many horse-power being absorbed at the dies and converted into heat. A lubricant is employed to reduce the friction—for example, soap as a dry, and the author has seen stale beer used as a wet lubricant. The use of a liquid leads to a superior surface finish of the wire, and increases the cooling effect.

The system or scheme for the drawing of wire, in accordance with which the number of passes and the reduction per pass is arranged, is too complex to discuss here. It may be noted, however, that the reduction of the sectional area of the wire is small at the first pass, in connection with which Adam refers to limiting the shock to the virgin rod,

then the percentage reduction is increased, but it is reduced again for the final pass. When the reduction is made by a small number of passes a hard wire results, whereas lessening the reduction per pass, which requires more passes, leads to a tougher wire.

Patenting takes place at a higher temperature, about 1,000° C., than is generally adopted for the heat-treatment of steel, the reason being that the metal becomes more homogeneous and of a suitable crystalline size and structure for the drawing. The steel is weak at first, however, hence the moderate first draw, but it is found that a few passes removes the effects of the high temperature.

The grain or crystal size controls the extent of the drawing which wire will stand, and also the test properties. The resulting wire is more fibrous when the original crystals are large, and a long fibrous structure gives good results for a torsion test, whereas shorter fibres lead to superior test results by bending. When both torsion and bending tests are specified for wire, it will be realised that the scheme of manufacture must be specially arranged. Adam states also that large crystals pass more uniformly through the die and lead to more ductile wire. The structure desired in the rod before drawing is described as sorbitic pearlite, which flows with equal freedom in all directions.

The physical properties of wire are very different from those of the steel from which the wire is drawn. The elastic limit and ultimate strengths are increased, the elongation and ductility are reduced, and the metal is hardened.

The tests which are applied to wire will now be dealt with. First, the tensile test, essential because wire has to be drawn within limits of strength, usually the range is 10 tons per square inch, specified, for example, as 100/110 tons per square inch. Now, it must be noted that a rope which is composed of 42 wires is of a simple construction ; 114 is a common number, and many more are often used. When each end of a coil is tested the number of measurements of each kind is twice the number of wires in the rope. The time taken for a test becomes a serious matter, and the cost is also an important consideration. Because of this, for a tension test of wire a large portion of the tension is usually applied quickly, possibly 80 per cent. of the ultimate strength, then the tension is increased more slowly to fracture. In general, the breaking tension is the only figure

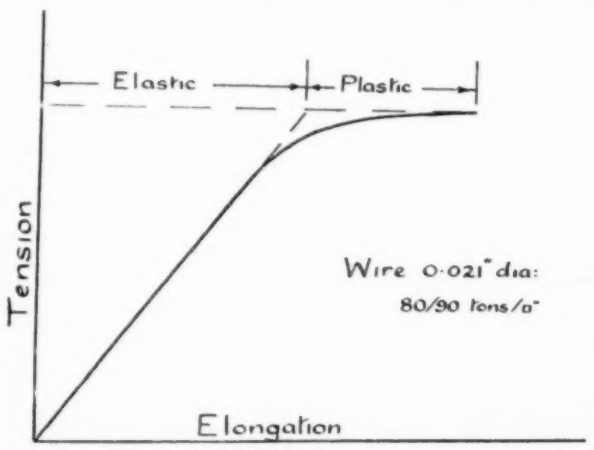


Fig. 3.

recorded, but a few specifications demand a minimum for the final elongation as an indication of the ductility of the wire. This measurement slows the test very appreciably, is difficult to make with accuracy, and it is by no means certain that it reflects the ductility as believed by those who include it.

The typical load-extension curve for a steel wire, given in Fig. 3, indicates the relative values of the elastic extension and the plastic elongation at fracture. The former is much larger than that for bulk steel, because the elastic limit and breaking stresses are high. If it is desired to form an estimate of the ductility of the wire from the tension test, the elastic elongation should be deducted from the total elongation at fracture before the figures are compared. The minimum elongations demanded by the American Petroleum Institute specification for wire rope vary from 1% for wire less than 0·020 in. diameter, to 2% for 0·070 in. diameter and larger.

The torsion test does not deal with the strength : the wire must stand a specified number of twists on a length equal to 100 times its diameter. Usually an 8-in. length is

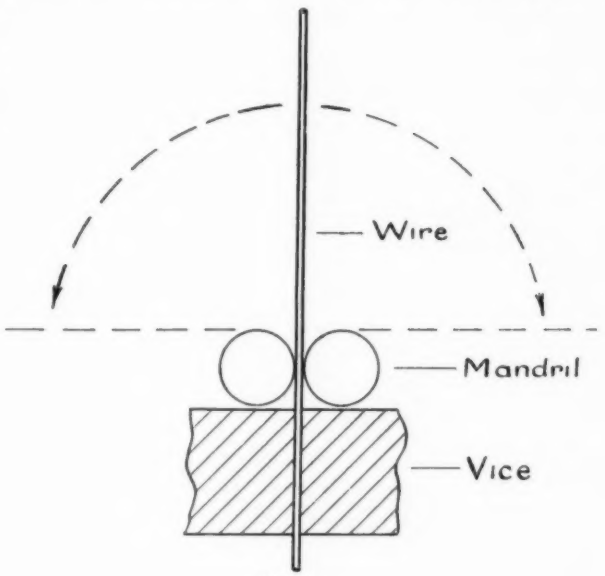


Fig. 4.

torsioned, and the number of twists is corrected for the length of 100 diameters. The wire should not split nor show surface defects during the test, and it should twist uniformly along its length. When wire is taken from a rope for test it is carefully straightened. The sample is held in two vices, one of which must be free to move longitudinally because the wire shortens as it torsions. Usually one vice is rotated by hand and the other is fixed, but sometimes the vices revolve in opposite directions.

The torsion test is firmly established in Great Britain, but it is by no means easy to state the deductions which may be made from the results. At first sight an engineer is likely to assume that high torsions indicate good ductility, and Adam states that this test is generally accepted as the standard ductility test for hard-drawn wire. The writer does not agree to this, indeed he has had excellent torsion results from extremely brittle wire. This test checks the homogeneity of the metal, or ensures uniformity of the wire along its length and freedom from surface defects. If a wire is weak at one point it may twist and break there under a torque which is not sufficiently large to cause yield at all places, thus the number of twists will be low. Also, the torque necessary to twist a wire is proportional to its diameter cubed. A surface defect will reduce the effective diameter and lower the torsions by providing a weak spot. Surface defects which have little or no effect on the tensile strength are readily detected by the torsion test. It does not seem fair to torsion wire taken from a rope because an unimportant nick, caused by one wire slightly indenting another, may appreciably reduce the number of turns.

Another test applied to wire is the bend test, which is not usually included in British specifications, but which finds greater favour on the Continent and in the United States. The wire is held in a vice, and is bent over a known radius through 90°. This bend is not counted. The wire is then bent through 180°, backwards and forwards, and the number of these complete bends before the wire

breaks is recorded. The radius may be 2½, 5, 7½, or 10 mm. according to the diameter of the wire. There is no doubt that this test indicates one kind of ductility, but the metal yields considerably and is broken after only a few bends, limited to fifty in some specifications and twenty in others. Objection is taken to bending by many because it is difficult to obtain consistent results, particularly between machines of different design, and even on different machines of the same make. The most satisfactory machine seems to be the Tarnogrocki, of German manufacture, the

Fig. 5.

Fig. 6.

peculiar feature of which is that the wire is held in a vice and is not gripped by the ground mandrils over which the wire is bent, Fig. 4.

Bend tests are useful to ensure that the heat-treatment before drawing was satisfactory, which fact was indicated earlier when it was stated that good bend results are opposed to high torsions. This latter fact supports the view expressed here that the torsions do not indicate ductility.

Many of the tests are subject to variations: for example, American practice requires a wire to be bent at right angles and back to the straight—that is, through 90° only.

Another test, which is intended to detect brittleness in wire, is the wrapping test. The wire has to be wrapped a given number of times round itself, Fig. 5, and unwrapped and straightened without breaking or splitting. The method used to detect brittleness by those accustomed to handling wire is the "snare" test, which, unfortunately, cannot be exactly defined and adopted for a specification. The wire is looped and pulled to close the loop, as illustrated in Fig. 6. Unsuitable wire will break or split under this treatment, and, when the operator is experienced, he can estimate the quality of wire fairly reliably in this way.

Roping wire is used either black—that is, as drawn—or galvanised. An old process has been revived to make drawn galvanised wire, the material being given a pass through a die after galvanising, with the result that the surface finish is improved, and the coating appears to be more continuous and in better adhesion to the steel, therefore affording superior protection than is given by plain galvanising. Occasionally wire is tinned to facilitate soldering, but tinning does not protect the steel. It is possible to tin over drawn galvanising when both protection and ready soldering are required.

The efficiency of the galvanising is tested by immersing cleaned wire in freshly-made neutral saturated solution of copper sulphate for a specified time, wiping clean and repeating for a definite number of dips. The wire must not show a deposit of bright copper after thorough wiping. Galvanising affects the mechanical properties of wire, and in particular reduces the number of torsions it will stand.

(To be continued.)

Nickel and Its Uses in Engineering*

PRIOR to the war the greater percentage of the world's nickel production was used in the manufacture of nickel steel for armament purposes, but on the conclusion of hostilities after the war nickel production dropped to a low level. Developments in metal compositions have, however, gradually increased the need for nickel, and consumption has now increased to as high a figure as any attained prior to or during the war. A considerable portion of the output is used in the radio electrical industry for parts of wireless valves, due to its high melting point, also for the electrodes of sparking plugs. In chemical engineering much use is made of it on account of its ability to withstand alkaline reagents. In mechanical engineering it is largely used by means of electro-deposition for building up worn parts of mechanisms; but its principal uses are found when alloyed with other metals—*i.e.*, in steels it increases their toughness, and in conjunction with heat treatment improves the homogeneity of castings; in casehardened articles it increases the penetration of the hardening material, and in many cases eliminates the preliminary heating and quenching.

In conjunction with chromium and molybdenum in steel, large forgings can be made, as the elastic limit of the material is improved. This property is specially important in such structures as bridges—the Quebec bridge is an instance. In Canada, nickel alloy steel is used in casting the bar framing of locomotives, and even boiler parts, including plates, firebox, and tubes, are there made of an alloy steel containing 2% of nickel, which enables the boiler pressure to be increased some 37% without increasing the weight of the engine. Certain European railways are experimenting with the use of nickel steel for similar purposes.

When alloyed with iron, nickel has the property, when present to the extent of about 25%, of destroying the magnetic properties of iron; but, strangely enough, a higher percentage of nickel restores these properties, and the Western Electric Co., of America, have established that after heat-treatment of high-content nickel-iron alloys the magnetic qualities were 10 to 13 times better than the best soft iron; it also had much effect in diminishing the hysterisis loss. These properties are of much use in submarine cables, where great permeability is desirable to ensure quick working. The alloy is insulated from but wound round the copper conductor, and prevents the interference of stray currents. An alloy of 35% nickel, 35% cobalt and iron, known as Permivar, showed great constancy of permeability. The addition of nickel to cast iron prevents the thin portions of castings becoming hard on cooling, and also does not open the grain of the larger portions.

In heat-resisting steels it prevents corrosion of the steel up to temperatures of 600—700° C. Nickel-chromium alloys are now largely used for electrical heating purposes; in a large annealing furnace ribbons of the alloy, arranged along the top and sides, provided the heating elements.

Nickel alloyed with copper increases the tensile strength of the latter from 21 to 45 tons per square inch, and it is now greatly used for condenser tubes, these, as compared with brass, having a long life without corrosion.

It is interesting to note that nearly all the nickel used in the world came from within the Empire, Canada producing 90% of it; there are also small deposits in New Caledonia.

* Extract from lecture before Junior Institution of Engineers by W. T. Griffiths.

Steels for Automobiles and Aeroplanes

By DR. HATFIELD.

Excellent work has been accomplished by the Author in connection with alloy steels, and the following extract of his review on available steels in the manufacture of automobiles and aeroplanes, read at a joint meeting of the Institution of Automobile Engineers and the Iron and Steel Institute, is of special interest.

THE technology of the production of both steel and its fabrication into its final forms has reached a very high level. During recent years there has been undoubtedly substantial advance in the standard of production of steel, as regards both reliability and characteristics; in the knowledge of the engineer as regards the stresses imposed upon his different parts, and the steps to be taken to carry them safely; and last, but not least, in the technique of the machine shops engaged in the fabrication.

Essentially, the steels used in automobile production are made either by the open-hearth process or by the electric process, and one of the outstanding metallurgical features of recent times has been the great growth in the tonnage of steel produced by the latter process. The refining conditions of the electric furnace permit of such a high standard of technique as regards the de-oxidation of the liquid material that it can be definitely stated that electric steel, when produced in a well-controlled modern works, is freer from non-metallic inclusions than the open-hearth product. As regards the rolling and hot-working of the steel generally, it can be said that considerable advance has been made in recent years in appreciating the optimum ranges of temperature during which the deformation resulting from the rolling and forging operations can be best carried out.

Regarding the heat-treatment of the steels, it is unquestionably a fact that on this side of the subject a very high standard of technique has been attained, resulting from a better knowledge of the metallography of the steels treated, combined with a more effective pyrometric control than was indeed possible in the early days; and of mechanical testing of the steels, both for reception purposes and for the provision of data upon which to base design, it can indeed be said that substantial advances have been made as regards the ampleness of the provision made for determining, not only the characteristics of the material, but also for checking the consistency with which the desired properties are attained.

Endeavouring to review the vast range of composition, Dr. Hatfield has been able to reduce the number of actual steels requiring, to his mind, detailed attention, to those shown in the accompanying table, in which will be found the typical analyses, heat-treatments, and tensile properties, including the proof stress, the results of izod and notched-bend tests, and also the results of fatigue tests (Wohler rotary-bend test, with the figures stated, representing 10,000,000 revolutions).

Class.		Analyses.								Condition.	Mechanical Tests in Condition as Used.					Izod.	Fatigue. ±
		C.	Mn.	Si.	Ni.	Cr.	Mo.	W.	Va.		Proof Stress 0·1.	Y.P.	M.S.	El.	R/A.		
1. Carbon steels	(*a*)	0·10	0·72	0·06	—	—	—	—	—	N.900.	16·2	17·5	28·5	37	64·5	65	12·0
	(*b*)	0·3	0·67	0·14	0·21	—	—	—	—	N.850.	17·5	20·7	35	30·2	54·6	32	13
	(*c*)	0·5	0·70	0·18	0·10	—	—	—	—	N.820.	22	26·0	44·2	24	43·5	18	17
	(*d*)	0·76	0·55	0·19	0·30	—	—	—	—	N.820.	28	45	63	16	25	3	19·5
2. High Mn.	(*a*)	0·41	1·5	0·19	0·12	—	—	—	—	W.H.850. T.620	27	32	46·8	25	58	20	20
3. Cr.	(*a*)	0·45	0·66	0·27	0·23	0·93	—	—	—	O.H.850. T.600.	52	58	66·5	20	52	40	28
	(*b*)	1·0	0·38	0·18	0·15	1·4	—	—	—	W.Q.830.	Hardness > 650 Br.			90 to 95 Scleroscope			
4. Cr. Va.	(*a*)	0·46	0·57	0·17	0·15	1·4	—	—	0·18	O.Q.850. T.490.	72	82·5	87·0	16	48	24	42
	(*b*)	0·46	0·57	0·17	0·15	1·4	—	—	0·18	O.Q.850. T.650.	32	48·0	56·0	22	60·4	55	25
6. Nickel	(*a*)	0·12	0·4	0·1	2·2	—	—	—	—	Refine 880. W.H.760.	16	23	38	32	65	80	15
	(*b*)	0·14	0·29	0·16	4·9	—	—	—	—	Refine 840. W.Q.760.	27	41·0	60·6	17·5	46·9	24	26·5
	(*c*)	0·39	0·55	0·11	2·96	—	—	—	—	O.Q.850. T.620	35	41·7	49·5	24	63·6	70	21·5
	(*d*)	0·43	0·64	0·19	3·58	0·20	—	—	—	O.Q.830. T.570. O.Q.	53	56·4	63·8	22	61	55	27·0
8. Ni. Cr.	(*a*)	0·31	0·70	0·14	3·2	0·75	—	—	—	O.H.820. T.600. W.Q.	50	54·5	60	22·0	61	68	26
	(*b*)	0·28	0·50	0·15	4·2	1·5	—	—	—	A.H.820 T.250.	65·2	85	106	12	45	12	45
	(*c*)	0·14	0·40	0·21	4·49	1·2	—	—	—	O.Q.760	48·3	73	89	18	63·7	30	39
9. Ni. Cr. Mo. Va.	(*a*)	0·21	0·54	0·20	3·07	1·5	0·56	—	0·18	O.Q.850. T.640. A.C.	66·8	70·5	74·6	21	67·0	48	32
10. Si.Mn.	(*a*)	0·52	1·05	1·95	—	0·05	—	—	—	O.H.870. T.520.	65	76·9	88·2	15	36	13	43

Even with this restricted range of steels, some further simplification is possible, and in what he has further to say, the author has in mind the following point of view. He considers that the number of steels employed should be as few as possible, but that the utmost technical exactitude should be attained as regards the standard of excellence from the point of view of reliability and freedom from defects. In other words, it is in the best interests to eliminate a number of steels and thus increase the tonnage required from each of those retained, and then to go to the necessary trouble and expense to see that such steels as have been selected are produced under the best technical conditions.

The number of existing specifications is considerable, and largely due to the fact that, as indicated, certain steels are being successfully employed by some people, whilst other steels are employed with equal success by others. The time has perhaps come to attempt unification with the resultant effect upon production.

NITRIDING STEELS—NITRALLOY.

One of the recent advances made in the field of materials applicable for the automobile industry is the discovery of certain steels which, under certain treatment in ammonia gas, acquire an intensely hard surface. These steels, known under the trade name of "Nitralloy," contain essentially about 1½% chromium, 1% aluminium, and carbon contents varying according to the characteristics of the core material desired, usually ranging from 0·2 to 0·65%. The case-hardening treatment consists merely of heating the articles in an atmosphere of ammonia at a temperature of 500° C., for periods up to 96 hours. No further heat-treatment is necessary, so that articles so treated may be put to immediate use. Further, the low temperature of the treatment produces no distortion in the articles, provided that internal stresses have been previously removed by tempering at temperatures above 500° C.

RUSTLESS SHEETS AND STRIPS.

The demands made on materials for aircraft purposes include, for certain parts, a combination of stainless properties with very enhanced mechanical properties. A high proof-stress is called for, as well as a substantial ductility, permitting severe bending and forming operations without fracture. While high mechanical properties have been adequately provided on strips and sheets made from carbon steels and nickel-chromium steels, these materials are naturally at a great disadvantage when exposed to the corroding influence of a marine atmosphere. Consequently, the production of stainless materials in strip and sheet form has been called for. Special skill and technique are necessary in both hot and cold-rolling operations, both processes being in use according to the dimensions and properties required. In cold-rolling intermediate heat-treatment between stages is necessary when substantial reduction of thickness is to be made. Good surface finish, flatness, and uniformity of thickness are only attained by close control and understanding of the various operations.

TREATMENT FOR MECHANICAL PROPERTIES.

The final mechanical properties of the materials are obtainable in two ways—heat-treatment or cold-working. With the 12 to 14% chromium class of steels, it is possible to apply heat-treatment operations, and the high-tensile tests asked for are obtained by hardening and tempering. The latter treatment develops satisfactorily the corrosion-resisting properties. The austenitic class of nickel-chromium steels, which have very enhanced corrosion-resisting properties without special treatment, are not amenable to hardening and tempering by thermal treatment. They can, however, be given substantial mechanical strength, while still retaining a high degree of ductility, by cold-rolling. The success of materials produced in this way is now well recognised. A proof-stress of 50 tons per square inch on cold-rolled austenitic non-corroding steel is a very satisfactory achievement.

ABRASIVES IN INDUSTRY.

By D. A. EYRE.

THE manufacture of artificial abrasives have profoundly influenced present day mechanical methods. It was in 1891 that Acheson, who had long been impressed with the possibility of producing an artificial abrasive, conceived the idea of using the electric furnace to produce a form of crystalline carbon which would possess some of the properties of the diamond and be useful as an abrasive. Iridescent crystals which he formed were in due time isolated as silicon carbide. In modern practice enormous quantities are made by the reaction of carbon and sand at the high temperature of the electric furnace. The discovery of the method of producing carborundum stimulated research in the production of other artificial abrasives and in 1899 Jacobs invented a process for making crystalline alumina or manufactured corundum in the electric furnace by the fusion of bauxite. This manufactured corundum has been given various trade names, such as alundum and aloxite. In chemical composition it is similar to ruby and sapphire, and not radically different from natural, but it differs in physical structure as the alumina crystals are bound together by a thin matrix of the impurities, thus giving it in higher degree the properties of hardness, toughness and uniformity, which are required in an abrasive suitable for grinding wheels. The artificial product has proved to be superior to the natural.

In making the abrasive into wheels there are two principal components, the abrasive grains and the bond which holds them together. Various materials are used as bonds, the principal ones being porcelain, silicate of soda, shellac, rubber, and the phenol resins, bakalite, and redmanal. The first requirement is the accurate regulation of the grade of the wheel to meet successfully the wide range of work. The variation in grade is obtained by varying the amount and character of the bond used, and by the subsequent heat-treatment or burning in a kiln. These operations require the closest scientific control in order that every wheel of a given grade and every portion of the wheel shall duplicate the grade standard. In addition to high centrifugal stresses from the high peripheral speed at which a grinding wheel revolves, it must withstand severe impact and tortional stresses from heavy castings and metal parts which are being ground.

An exhaustive description of the wide variety of uses of manufactured abrasives in industry would involve all the useful arts. In the mechanical arts the big contribution of abrasives to quantity production is the precision grinding machine and grinding-wheel. The machine is unique in that it combines quantity production with the utmost refinement and accuracy. Thousands of machine parts can be produced, each one varying from the other not more than the fraction of one-thousandth of an inch. On hardened steel, where the lathe tool may fail, the precision grinder has made possible the use of hardened steel crank-pins, spindles and wearing parts in machines of every variety. The manufacture of steel balls or ball bearings illustrates the degree of accuracy attained. The manufacturing limit is one-half of one-ten-thousandth of an inch, but some manufacturers reduce this limit.

It is not possible to refer to all the bonds used for the many varying purposes, but the most widely used is the porcelain bond-wheel, made by the vitrified process. Many problems in manufacture have been successfully solved, and among all ceramic articles, this form of grinding-wheel may be regarded, from mechanical considerations, as the highest achievement of the ceramic chemist. In making these vitrified grinding-wheels the abrasive grains are first mixed with clay, feldspar, flint or other ceramic materials, and moulded to shape by pressing or puddling. The shapes are then fired in kilns to a temperature of about 1,300° C. for a period of four to five days, thus vitrifying the clay bond. After removal from the kiln the wheels are trued in a lathe, bushed with lead and subjected to speed tests before being ready for use.

METALLURGIA

The British Journal of Metals.

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British Salesmanship

THE Committee on Education for Salesmanship that was appointed on October 13 of last year has issued an interim report which is being severely criticised in certain quarters, although it would appear to be a very fair analysis of British sales organisation as a whole. The Committee consists of thirty-two members, and all of them are successful business men, thus their findings are worthy of the most careful attention. The chairman of the Committee, Mr. Francis W. Goodenough, is the chairman of the British Commercial Gas Association and of the Education Committee of the Institution of Gas Engineers. Sir William J. Larke, K.B.E., another member, is, of course, a director of the National Federation of Iron and Steel Manufacturers, while engineering is also represented on the Committee by Mr. P. J. Pybus, who is a director of the English Electric Co., by Sir Edward Manville, Chairman of the Daimler Co., and of B.S.A., and Sir Harold Bowden, Bart., a Vice-President of the Federation of British Industries. The terms of reference of the Committee were to consider the problem of education for salesmanship, and to make any recommendations for action that, following such consideration, might appear desirable for the promotion, by means of education, of greater efficiency in the marketing of British goods and services, at home and overseas.

The interim report is of interest to both the ferrous and non-ferrous metal industries, and it is very correctly stated that salesmanship is a prime function of direction and supreme management. It certainly embraces the study of the fundamental principles of commerce and the planning of policy based upon them as well as the selection, training, and direction of the personnel required for translating policy effectively into action. A very exhaustive inquiry would appear to have been already undertaken with the help of the Department of Overseas Trade, of the Association of British Chambers of Commerce, and of the Federation of Chambers of Commerce of the British Empire. Evidence and material have been collected from the various British colonies, and practically all foreign countries, and no attempt is made in the interim report to present a picture of the organisation and characteristics of British overseas trade. Some of the critics of the report would appear to have read it only superficially, because, while it is suggested that the general level of prosperity of British trade must depend on the merits of the average firm, and these are not always of too high an order, yet the Committee frankly acknowledge that many firms and associations of firms reach a high and, in some cases, the very highest standard of efficiency, and have evolved systems of salesmanship that are thoroughly admirable and sufficiently flexible to meet the rapid changes in the conditions of modern markets. It can be stated without fear of contradiction that while some important British industries are languishing chiefly through bad salesmanship, in the case of the iron and steel and non-ferrous metal industries there is an efficient sales organisation, but the trade depression is due to factors that cannot be remedied by the industries themselves, such as the low standards of living in Continental countries that are chief competitors, and also heavy fuel and freight charges.

There is not much matter for contention in the interim report, the keynote of which is that the customer is always right. One witness giving evidence before the Committee emphasised the need for manufactures that are produced by large-scale methods being distributed by organisations adapted to place the goods, if possible, actually in the home of the consumer or on the spot of consumption, with the least possible trouble to the eventual purchaser. It is not always realised that the iron and steel manufacturer, for instance, may lose heavily through the inefficient sales organisation of those who are his customers. A Spanish correspondent of the *Spectator* made the statement recently that if British motor-car manufacturers are to compete against German firms in Spain, they will have to start quoting prices in Spanish currency, and make it more easy for the customer to obtain delivery of a car; he very rightly contended that delivery difficulties were the manufacturers' affair, and not the customers, and the Association of Chambers of Commerce has emphasised that details such as weights and measures should be those in local use. In the interim report an incident is recorded in connection with the discharge and bunker trimming of coal in Chile, where the handling of the coal is done by a special type of shovel, light, and rather fragile, which it is customary to throw away at the end of a particular cargo. An English agent offered to sell a better and more costly shovel which would last for many cargoes, but the coal merchants did not appreciate the cost and trouble of collecting and re-issuing shovels, and consequently the order went to a German firm that provided what was required. Another incident worth recording is reported from Brazil, where an English firm endeavoured to sell a much better type of hoe than is customarily used. A local German agent obtained samples of the types of hoe in use in the country, sent them home to his works, had them manufactured accordingly, and captured the market.

It would appear that while, in many of our industries, our production methods are exceptionally up to date, the same cannot always be said about our selling methods. The pressure of foreign competition is more keenly felt to-day than ever before, and it is well that we should realise that our competitors are placing manufactures of good quality in the various markets and are conducting intensive trade campaigns. Foreign competition enters practically all trades, including those which a few years ago were almost exclusively British. One of the most interesting passages in the report concerns direct

FORTHCOMING ARTICLES

"**Choice of Raw Materials in Malleable Cast Iron.**" By J. V. MURRAY.

"**Thermal Conductivity of Metals and Alloys.**" By J. W. DONALDSON, D.Sc.

"**Notes on the Centrifugal Casting Process.**" By J. E. HURST.

"**Modern Methods of Heat-Treatment.**" By SAMUEL WHYTE, B.Sc.

"**Principles and Uses of Wire Rope.**" Part III. By W. A. SCOBLE, D.Sc., M.I.Mech.E.

"**Aluminium Alloys for Castings.**" By A CORRESPONDENT.

"**Refractory Materials.**" Part III. By COLIN PRESSWOOD.

"**Common Errors in Steel-Making.**" Part II. By WALTER LISTER.

"**Future Developments in Die-Casting.**" By D. RICHARDS.

"**Notes on Iron and Steel Foundry Practice.**" By BEN SHAW.

representation abroad, and in this respect the Committee expressed the opinion that, both as regards quality and quantity, many British traders have not moved with the rapidly changing times. There is not unanimous agreement as to the value of technical knowledge to a salesman, but, while it may be admitted that some salesmen may weary customers with technical dissertations, yet it is a heavy handicap for a salesman of engineering goods of any kind to be without technical and practical knowledge. In foreign countries what is as important as technical knowledge is an intimate acquaintance with the language of the country. Foreigners have realised the commercial value of a knowledge of languages other than their own more than we have done, but this has no doubt been more of a necessity than a virtue, although it ought to be recognised in this country now that a knowledge of foreign languages by overseas representatives will determine largely the future measure of British overseas trade prosperity.

British business is indebted to the Committee on Education for Salesmanship for telling it some plain truths, and it is fortunate that invocations of "British prestige" have not impressed them. It is all to the good that this country is taking stock of its trade position, and is recognising that it will always in the future have to face both American and Continental competition of the keenest kind. But it must not be forgotten that good salesmanship alone is not enough, nor are the most excellent production methods, unless means are taken whereby competition between the various countries will be of an equitable kind.

THE BRITISH CAST IRON RESEARCH ASSOCIATION.

THE British Cast Iron Research Association is doing valuable work. It is endeavouring to reduce the difficulties associated with the production of castings, and is gradually raising the standard of quality in production to a higher and more scientific level. In view of the good work that has been done by this Association, it behoves all who are associated with the iron foundry industry to render it reasonable support. It needs reasonable financial security to ensure the maintenance of a permanent organisation. It should not be necessary for an organisation doing research work of national importance to bother about a staple income; continuity of progress of this character should be assured. Considerable progress has already been made, and it is largely to the credit of the work of the Association that modern requirements are being met to a remarkable extent. In this connection the report of the Department of Scientific and Industrial Research contained the following statement:—"It is interesting to note that the experimental retorts, which were constructed to the design of the Cast Iron Research Association and made of special material recommended by them, have shown no signs of distortion after fourteen months continuous operation. This is a most satisfactory result, since the commercial success of this plant will probably rest very largely on the life of the retorts. No other retort yet tested at the Fuel Research Station has had so long a life without measurable and even serious distortion."

The revenue of the Association in the past has been supplemented by a grant from H.M. Government, and it is gratifying that the Advisory Council of the Department of Scientific and Industrial Research have been instrumental in extending the grant on the original scale until 1931, subject to certain very necessary conditions. In order to secure full advantage from this offer, the income of the Association must be increased, and this can best be effected by increasing the members. Viewed entirely from a selfish point, and a prospective member is quite justified in inquiring what he is likely to get in return for his subscription, the Association perform the function of a works laboratory in prescribing cast irons of suitable composition for particular classes of work, or make a real effort to reduce difficulties that may apparently be insurmountable. In effect, the economic advantages of membership are made clear by Mr. W. Turner MacLellan in his presidential address at the annual luncheon of the Association recently. "The members of the Association, he stated, "had temporarily at their disposal a machine which embodied both scientific knowledge and practical experience, and which further devoted a part of its activities to increasing steadily our knowledge of the remarkable range of alloys we called cast iron, as well as of related materials and processes." There is every likelihood that continued research with a view to improvements in the quality of cast iron will widen its scope and extend its usefulness.

Research work on such a complex metal as cast iron necessitates scientifically trained men who have specialised on this material, and who are available in the organisation of the Cast Iron Research Association, which should be used to the utmost by the industry.

SUCCESS.

THE reception accorded to the first issue of METALLURGIA was extremely gratifying to the publishers. A large number of congratulatory letters have been received from all parts of Great Britain, and we would take this opportunity of thanking our well-wishers.

Launching a new journal approximates in some ways to the staging of a new play. It is impossible before the journal has actually been published to state with any degree of accuracy what its reception is going to be. Unlike a play, a new technical journal must be an asset to the science or industry it represents, and it must win the enthusiasm of the right kind of subscribers and men with specialised knowledge to contribute to its literary columns.

Doubt has been expressed as to whether the high standard set by the first issue of METALLURGIA can be maintained; we can assure our readers that not only will it be maintained, but it will be improved.

Forthcoming Meetings

INSTITUTION OF MECHANICAL ENGINEERS.

Jan. 3. At 6-0 p.m., Thomas Lower Gray Lecture by Eng. Vice-Admiral R. W. Skelton, C.B., C.B.E., D.S.O. (Member of Council) on "Progress in Marine Engineering."

INSTITUTE OF METAL.

Jan. 9. "The Aluminium Industry," by George Mortimer, Esq. London Section.

Jan. 13. "Extrusion and a Consideration of Some of the Physical Properties Affecting the Production of Rods, Tubes, and Sections by this Process," by A. Wragg, Esq. Scottish Section.

Jan. 14. "Chromium Plating," by L. Wright, Esq. North-East Coast Section.

INSTITUTE OF MARINE ENGINEERS.

Jan. 14. "Water Tube Boilers for Merchant Ships," by Eng. Rear-Admiral W. M. Whayman, C.B., C.B.E. (Member).

THE INSTITUTE OF BRITISH FOUNDRYMEN.

Jan. 3. "Some Foundry Facts and Fancies," by C. Cleaver, Esq. London Branch.

Jan. 4. "The Influence of Manganese on Cast Iron," by H. Forest, Esq. West Riding and Yorkshire Branch.

Jan. 4. "Aluminium," by N. C. Aston, Esq. Lancashire Branch.

Jan. 8. Visit to Works of English Electric Co., Ltd., Rugby, arranged for members of Birmingham, Coventry, and West Midlands Branch.

Jan. 10. "Moulding Sands," by G. A. Adler, B.Sc. Middlesbrough Branch.

Jan. 11. "The Cupola," by A. G. Millar, Esq. Scottish Branch.

Jan. 11. "Jobbing Moulding," by S. Southcott, Esq. Wales and Monmouth Branch.

Correspondence.

Tungsten-Carbide Tools as Aid to Production.

Following an article on the above subject in our last issue, we have received the following letter :—

The Editor, METALLURGIA.

Dear Sir,—There is a general impression that tungsten-carbide cutting materials are not successful when applied to machine a face involving an intermittent cut. It will be of interest to those who have this impression to learn that intermittent cutting is done as easily as continuous cutting. The following performance demonstrated that intermittent cutting may actually enable the maintenance of a high speed. The performance refers to the machining of 14 cast-iron framings machined on a Duplex Webster and Bennett vertical boring mill. The casting had an outer diameter on the face of 36 in., and an inner diameter 10 in. The depth of the roughing cut varied from $\frac{1}{4}$ in. to $\frac{5}{16}$ in., with a feed of 32 per inch. From 36 in. diameter to 24 in. diameter the cut was broken four times per revolution; from 24 in. diameter to 16 in. diameter, eight times per revolution; and back again to four times per revolution for the remainder of the cut.

Using 18% tungsten steel, the speed was changed four times when crossing the face, the speeds being 9·2, 11·2, 14·3, and 16·1 r.p.m., giving an average cutting speed of about 86 ft. per min. for the roughing cut, which was $\frac{1}{4}$ in. to $\frac{5}{16}$ in. deep, with 32 per inch feed, and for a finishing cut taken at the same speeds 0·025 deep and 16 per inch feed.

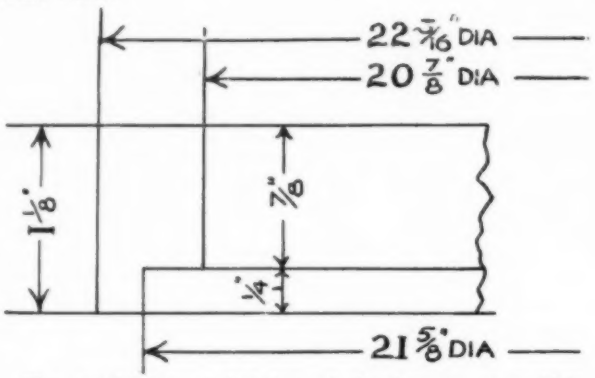
With a tungsten carbide cutting material the speed for the roughing cut was 25 r.p.m., the cut being $\frac{1}{4}$ in. to $\frac{5}{16}$ in. deep, 36 per inch feed, and for the finishing cut 50 r.p.m., 0·025 deep, 16 per inch feed, equal to a maximum and minimum speed of about 235 to 65 ft. per min. at the outside and inside diameters of face for the roughing cut, and 471 to 130 ft. per min. for the finishing cut. It will be noted that no attempt was made to alter the speed of the machine while using a tungsten-carbide tool, for various reasons: first, because tungsten carbide will chip if the machine is stopped, or partly stopped, with a heavy cut on; second, in view of the fact that to run the cut-off by stopping the feed and then changing the speed would take more time than the increased change in speed could save. The roughing feed of 36 was used because a change to 16 was a very simple operation, and showed a saving in time and manipulation.

The roughing and finishing tungsten-carbide tools stood up for the complete run of 14 framings, and also completed the machining of the six feet and two faces on the other side of the framings. The resultant times taken for the complete machining of the top and bottom of the 14 framings, when using 18% tungsten-steel and tungsten-carbide tools, were 72½ hours with tungsten steel and 41½ hours using tungsten-carbide tools.

The 14 top casings for these framings were also machined with tungsten carbide. The joint face was machined at 42 r.p.m. with a $\frac{3}{16}$ in. roughing cut and 32 per inch feed, and the finishing cut at 50 r.p.m. with a cut 0·025 deep 16 per inch feed. The round flange on the other side (which was presented to the tool in a rigid manner) was machined with one cut off the face and diameter at 50 r.p.m., with a cut $\frac{3}{16}$ in. deep and 36 per inch feed. In this case the increase in cutting speed was not so great; nevertheless, owing to the tungsten-carbide tool being able to machine the round flange with one cut and to bring the joint face off flat in two cuts, the saving on the job was well worth while.

Total time on 14 casings with 18% tungsten steel, 46 hours; total time on 14 casings with tungsten carbide, 20 hours.

Another example of intermittent cutting refers to the machining of six cast monel-metal impellers, each 14½ in. diameter. In this instance the tungsten-carbide tool was put to a very severe test while crossing the blade tips at 90 r.p.m., with a reduction of $\frac{1}{2}$ in. on diameter at 96 per inch feed, there being 900 interruptions per minute. The tool showed a tendency to chip, probably due to the tool not being presented to the job with a shearing cut, and to the lathe having a tendency to over-run between the cuts. This part of the job was done on the remaining five impellers with an 18% tungsten-steel tool, set with a shearing cut, with the speed reduced to 80 ft. per minute and a feed of 36 per inch. The sides of all six impellers were machined with tungsten carbide from a 14 in. diameter down to 4 in. diameter, at 330 ft. per min., with a cut $\frac{3}{16}$ in. deep and 36 per inch feed, without sharpening the tool. This was about three times faster than 18% tungsten-steel tool would cut, and which would have required sharpening at least twice.



The machining of batches of diaphragms on a 42 in. vertical boring mill was accomplished entirely with tungsten-carbide tools, excepting the ones used for boring the hole. The machine was worked at its highest speed. Only one cut was taken across each face at 74 r.p.m., representing a speed of 444 ft. per min., with $\frac{5}{16}$ in. to $\frac{3}{8}$ in. deep cut, and 55 per inch feed; the horse-power required was 20, approximately. The tools were in good condition after machining a batch of ten.

When using tungsten carbide on the outer diameter and sides of a cast-iron flywheel 30 in. diameter, 6 in. wide, cutting at 240 ft. per min., with a cut $\frac{1}{4}$ in. deep and 56 per inch feed, a very good finish was obtained, and no subsequent finishing cut was required.

In machining large ebonite rings similar to sketch the writer tried a tungsten-carbide tool which produced a very good finish, with a considerable saving in time, due to the tool being able to remove the surplus material with fewer cuts. Previously a diamond tool had been used on this work. A quantity of about 250 of these rings were machined at 700 ft. per min., with 64 per inch feed. Three tungsten-carbide tools formed to produce the section were used, and these were sharpened ten times during the machining of the 250 rings completed.

The use of tungsten-carbide tools forming a set in a turret lathe has shown up well in the machining of large forged, bronze and iron nuts, the cutting speed across the corners being 540 ft. per min. The set consisted of a boring bar, a roughing and a finishing facing tool. A similar set up consisting of a roughing, a scraping, and a chamfering tool, were also used in machining the other side of these nuts in a special machine. The cutting speed was 270 ft. per min., it being limited by the capability of the machine, and, although this does not compare with the speeds obtained elsewhere when using tungsten carbide, nevertheless a saving is effected, due to the tool standing up almost indefinitely, which makes its use well worth while.

The writer has not made any extensive trials of tungsten carbide on steel, either in the form of castings or forgings, its use on steel having been confined to cutting hard parts and welds in castings, where it is superior to high-speed steel in so far as it does not leave lumps at the hard parts, but cuts through them leaving the faces flat.—Yours faithfully,

MACHINE-SHOP MANAGER.

Glasgow.

ELECTRIC HEAT-TREATMENT OF METALS

By W. J. MILLAR and A. G. ROBIETTE, B.Sc.

(Continued from Last Month.)

IN order that no avoidable heat units are allowed to escape from furnaces, new heat insulation problems have been introduced as a result of electric heating. Electric furnaces require to be heavily lagged with heat-insulating material, the doors must be designed to obviate heat losses, and the charging equipment designed to facilitate external charging, in order that the doors are opened for a minimum of time. The tube furnace shown in Fig. 2 embodies these features.

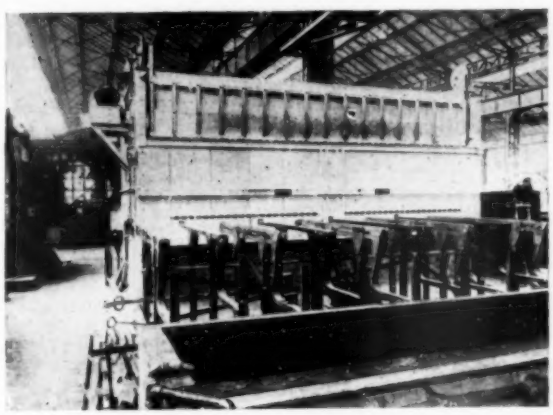


Fig. 2. Side-charged Tube Furnace.

An electric furnace of recent design is a continuous billet-heating furnace. It is of the double-ended type, from which the billet can be removed at one end for treatment in the rolling-mill or extrusion press, while another is inserted in the other door, maintaining a constant reserve of billets to meet requirements.

A special feature incorporated in the electrical design of this furnace is the grading of the resistor elements, which latter are so arranged that the maximum energy input is at the charging end, where the heat is needed to raise the cold billets up to temperature, while at the discharge end only sufficient heat is supplied to keep the billets at the soaking temperature—*i.e.*, to overcome radiation losses, which are extremely low in this efficiently lagged furnace.

Another very efficient method of heat-treating rods and tubes is by the ingenious Snead apparatus, Fig. 3. This makes use of the electrical resistance of the tubes to be annealed, and is undoubtedly the ideal technical solution of the annealing problem.

In construction, it consists of a horizontal bench about 25 ft. long, with two clamps for holding the tubes, the clamps being worked by solenoids. One of these is fixed and the other is on a movable carriage. The tube is then heated by a low-tension current, and as it expands the carriage on which rests one of the clamps moves, and the amount of displacement is registered on a dial. This dial can be set so that when the desired expansion (and consequently temperature) is reached an adjustable finger makes contact with the pointer, the contactor switch is automatically tripped, and the solenoids release the tube, which rolls down on to a bench below. The process is an extremely rapid one, and takes only 4 secs. in the case of brass tubes.

This apparatus is particularly adapted for the low-temperature annealing of brass tubes. This is carried out to release the internal stresses left over from the cold work operations, and so confers complete immunity from season cracking. This apparatus has a remarkably high thermal efficiency, and in attaining a temperature of 350° C. the power consumption amounts to only 43 k.w. per ton, with an output of 200 tubes per hour.

It has found application in the heat-treatment of tubes of duralumin, nickel, and monel metal, while it is even used for normalising steel.

The advent of alloy steels in modern engineering has largely been responsible for the corresponding improvements in the heat-treatment of steel. It was not realised before what variation in temperature meant in this connection, and strict temperature control is not only desirable but indispensable to overcome defects experienced in the heat-treated articles, and one might even say, in the case of alloy steels, that no heat-treatment is possible unless the temperature limits are rigidly adhered to.

Taking the well-known nickel-chromium steels as an example, steel of the common composition—carbon 0·35, nickel 3·5, chromium 1·3—when cooled in air from 814° C. gave a transformation point (Ar_3) at 637° C., and had a subsequent Brinell hardness of 231, while after heating only to 838° C. and similarly air-cooled, the transformation at 637° C. was almost completely inhibited, and it showed a larger arrest at 440° C., having now a Brinell hardness number of nearly 400.

Nearly all alloy steels which rely upon the solution of complex carbides for their hardening characteristics exhibit this marked susceptibility to the effects of superheating, and in this category may be classed the nickel-chromium, chromium, tungsten, and high-speed steels. These figures almost speak for themselves, and the disadvantages of a heating medium where strict temperature regulation is not possible are plainly evident. It is common knowledge that the transformation from α γ iron is accompanied by an abnormal volume change (contraction). This means that it is possible for one part of a piece of steel to be expanding while another part is contracting, if there is a temperature difference between the two points. This would naturally cause distortion, and perhaps be accompanied by the development of cracks. Moreover, the hardness will vary over the whole specimen, with the almost certain appearance of soft spots. This exemplifies a case where the cost of heating is only a secondary item in the balance-sheet, and is more than repaid by the saving effected with the elimination of rejections and by the higher quality of the resulting product, for which there is such a growing demand in the case of steels.

High-speed steels require a special heating operation owing to the brittle nature of the material. It must be heated very slowly up to about 700° to 800° C. (Cf. glass), but once the carbides commence to go into solution the steel may be heated quickly to its quenching temperature, 1,300° C. A furnace has been designed to meet these needs, and it comprises two separate heating chambers. In the first, the steel is heated slowly and uniformly by radiation from nickel-chromium alloy resistor elements. When it reaches a temperature of about 800° C. it is transferred into the high-temperature chamber, which is heated by elements of the non-metallic carborundum type. Furnaces heated in this latter way are also suitable for the heat-treatment of high-chromium steel, such as stainless iron and the nickel-chromium soft stainless steels.

A question which has aroused considerable attention, especially in the non-ferrous trades, is that of bright annealing. In the particular case of copper, the usual remedy to prevent excessive oxidation—that of using a flame carrying excess of gas—is inadmissible, since in a reducing atmosphere it is well known that copper develops the phenomenon of gassing, whereby the oxide present is reduced with the formation of gaseous products, causing inter-granular cracking or blisters. With an electric furnace there is no difficulty in controlling the atmosphere, and with the case in point, copper has been successfully bright annealed in an atmosphere of super-heated steam at a low pressure. The heating elements can be placed directly in the heating chamber, and no muffle, with its attendant maintenance, risk of cracking, and poor temperature control is necessary.

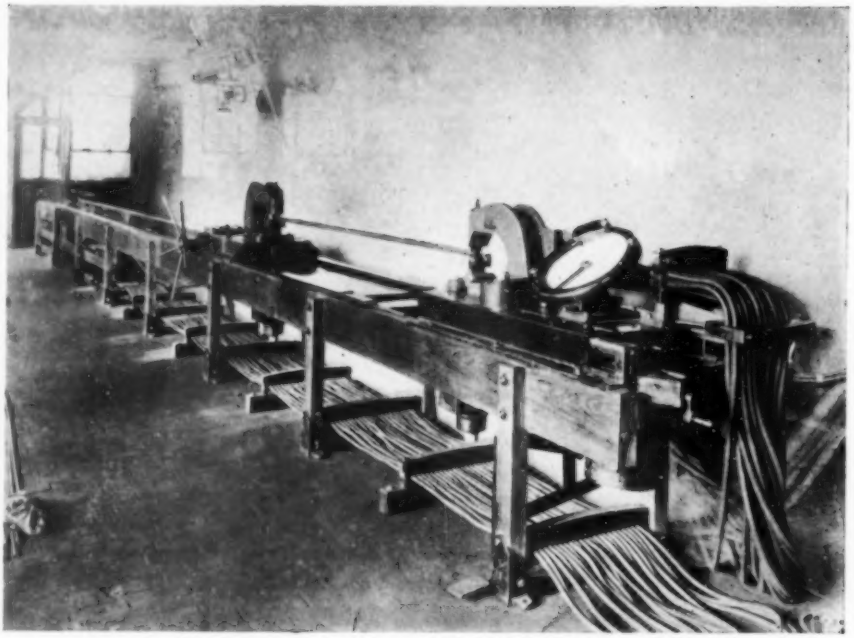


Fig. 3. The Snead Apparatus shown here uses the resistance to electricity of metal to be heat-treated and the expansion of the metal to control a temperature-indicating mechanism.

Bright annealing has also been achieved in other fields. Certain high-nickel alloys, which cause considerable difficulty in the pickling operations, have been successfully annealed in an atmosphere of nitrogen. In the case of brass, difficulties arise when annealing is carried out in both reducing and inert atmospheres, due to discoloration caused by surface dezincification. A furnace, however, has been designed for brass-strip annealing, which, although not being a bright annealing process in the strict sense of the term, at least overcomes many of the defects of the older strip-annealing process. (Fig. 4.)

In construction, the furnace consists of three flat heating chambers, about 20 ft. long and 3 ft. 3 in. wide. The process is a continuous one, the strip being passed through the furnace by a mechanism of unwinding drums. The furnace is heated by resistor elements in the hearth and roof, and the strip hangs in the furnace in the catenary form. As compared with gas-fired furnaces, it has been found that electric heating gives a finer and more even oxide film, owing to the prevailing uniformity of temperature. Consequently, only a light pickling, requiring a fraction of the time previously necessary, is needed, and the surface is left bright without any stains incurred by gas-heating.

In the case of a furnace annealing 63 : 37 brass, the output of a chamber 3 ft. 3 in. wide is 5 tons per 24 hours when treating strip 0·5 mm. thick. The rating of such a furnace is 60—100 k.w. (the latter power only being used when reheating after stoppage), while the power consumption, at a temperature of 700° C., varies from 60—100 units per ton.

Turning to the chemical heat-treatment processes of carburisation and nitration, the same tendency to electrify is working its influence (if the manufacturer is to be assured of a uniform product). In carburising, there are so many variable factors, such as time of heating, temperature of carburisation, nature of carburising medium, that it becomes extremely desirable to pin down one of them—namely, the temperature of carburisation. With the

(*Continued on page* 74.)

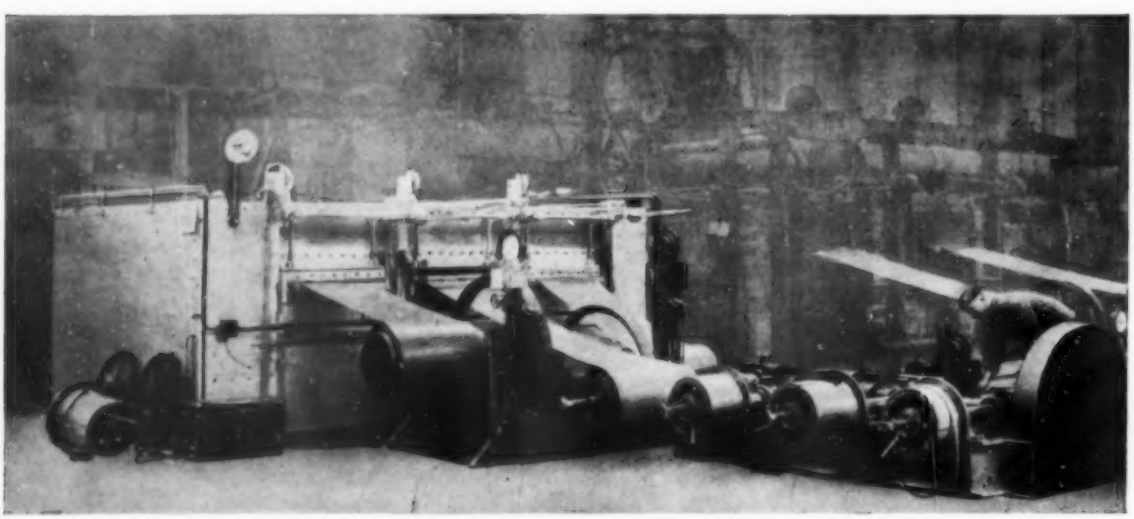


Fig 4. Continuous Strip Furnace.

Light Alloys in Engineering

Developments have perfected their properties and they are now extensively used on an economic basis.

By Samuel Whyte, B.Sc.

THE history and development of the now universally employed light alloys is a romance of modern civilisation, and the rapid evolution of the light-alloy industry is one of the wonders of the age. During the war alloys of aluminium and magnesium were first used as constructional units for aeroplanes and airships, and to-day their properties have been so perfected that they are employed not only for aircraft, but are used extensively on an economic basis for all other vehicles of transport—automobile, rail, and even marine. In the wonderful speeds achieved in the recent Schneider Trophy race, no small portion of the praise should go to those metallurgists whose researches have given the aero-engineer his ultra-light constructional materials.

The metals aluminium and magnesium form the basis of the light-alloy industry, and of these aluminium and its alloys are still the more important. The importance of light alloys in engineering is due to the low specific gravity, the malleability and ductility, and the high electrical and thermal conductivity of these metals.

Pure aluminium is soft, and of comparatively low tensile strength, but is used extensively in sheet form for panel work, for cooking and other household utensils, for vats, tanks, etc., in the chemical industry, and, in the form of wire, has a wide application in electrical engineering, particularly high-voltage transmission.

Sand-cast aluminium has a tensile strength of 4·5 tons per sq. in., with an elongation of 20%. After rolling into sheets or drawing into wire the tensile strength is raised considerably although the elongation is reduced. Hard rolled sheets have a tensile strength of 9 tons per sq. in., and an elongation of 2 to 8%, while drawn wire, which has had the maximum amount of work, has a tensile strength of about 12 tons per sq. in., and an elongation of 4% to 7%. During the rolling of panels, it is usually necessary to anneal at 350° C., otherwise the excessive cold working produces cracks. This annealing brings back the ductility of the original metal.

RELATIVE CONDUCTIVITY.

Its high conductivity, combined with low specific gravity makes aluminium an important rival to copper for electrical conductors. The actual conductivity of aluminium is only about 60% of copper, but taking into consideration the great difference in specific gravity, even allowing for wider cross-sectional area, the economic conductivity of an aluminium is actually 40% higher than that of copper. The tensile strength of aluminium is lower than that of copper, but here again the differences in specific gravity and conductivity enable larger sections to be used, and makes the former a better proposition economically. Aluminium wires are particularly suitable for aerial conductors owing to their superior resistance to corrosion. Steel wires are frequently enclosed in aluminium cables to increase their tensile strength, and these "steel aluminium cables" are amongst the conductors with the maximum strength hitherto produced.

ALLOYING ELEMENTS.

Pure aluminium, even in the hard-rolled condition, is a weak material for construction, and strengthening is brought about by the addition of alloying elements, such as copper, magnesium, silicon, zinc, nickel, manganese, and, what is generally considered an impurity, iron.

Of the many alloys which have been produced, duralumin was the first to be used, and even now has the widest application. This alloy contains 3·5 to 4·5% of copper, with small percentages ranging from 0·4 to 0·7% magnesium, silicon, manganese, and iron. Duralumin can be rolled or forged, and is generally used in the wrought condition, as its high physical properties are dependent on the application of mechanical work. The wide application of duralumin is mainly due, however, to the fact that its physical properties may be still further enhanced by a process of heat treatment, involving heating for a varying period of time at 475° C., quenching in water, and allowing to remain at ordinary temperatures for several days. Duralumin and similar alloys, quenched as above, after several days have their hardness and ductility raised by 15 to 50%, depending upon the composition of the alloy and the quenching temperature. This phenomenon of "age-hardening" is due to the slow precipitation of intermetallic compounds from the solid solution produced by soaking and quenching at high temperatures. Duralumin alloys strengthened by this process of quenching and ageing may be still further hardened by the application of cold work.

In the fully heat-treated condition duralumin has the following properties :—

Quality.	Tensile Strength. Tons per Sq. In.	Elastic Limit. Tons per Sq. In.	Elongation. %
Sheets, A–Normal	25	13·5	20
B–Normal	26	15	15/20
B–Hard	30/32	20	10/12
Rod, B quality..	25/30	16/22	10/20
Wire, A quality..	25/35	16/25	6/20
Tube, B quality..	28	16/18	15/18

"Y" ALLOY.

Closely allied to duralumin is the "Y" alloy largely used for sand and die castings in this country, which was developed by the National Physical Laboratory. "Y" alloy differs from duralumin in containing nickel and a higher percentage of magnesium. Its average composition is as follows :—

	%
Copper	3·5 to 4·5
Nickel	1·8 „ 2·3
Magnesium	1·2 „ 2·7
Silicon	nil „ 0·75
Iron	nil „ 0·75

In the cast condition "Y" alloy gives a tensile strength of 13 to 14 tons per sq. in., and after heat treatment of 20 to 22 tons per sq. in. The quenching of "Y" alloy is carried out at a slightly higher temperature than duralumin, and the alloy is generally given an ageing period of five days. "Y" alloy, like duralumin, may be worked by forging and rolling. Forged "Y" alloy has a tensile strength of 27 tons per sq. in, and an elongation of 24%.

"Y" alloy is the most widely used heat-treated casting alloy in this country. Its high tensile strength makes it very suitable for highly stressed parts where weight has to be considered, such as aeroplane structures, and the presence of nickel enables it, unlike most other aluminium alloys, to retain its strength at high temperatures. It is particularly suitable for pistons and for parts such as connecting rods of air-cooled radial engines. There is a steadily growing demand for "Y" alloy castings, both in the aircraft and automobile industries.

Binary alloys, which have had wide application in America and Germany, and which are finding more universal use in this country, are those containing 8 to 15% of silicon under the trade names of "Alpax," "Wilmil," "Silumin," etc. Silicon has a lower specific gravity than aluminium, and these alloys are therefore lighter than pure aluminium, and so are being used extensively where lightness is of major importance.

SILICON ALLOYS.

In the cast condition the tensile strength is only from 10 to 12 tons per sq. in., with 7 to 10% elongation. The impact value is, however, good, being 6 to 8 ft.-lb. The value of the aluminium silicon alloys lies in their exceptionally good casting properties. Owing to their high fluidity, these alloys produce remarkably sound castings of very thin section and intricate design. A very fine grain is produced by a process of "modification," which is applied to those alloys containing high percentages of silicon, and involves the addition of metallic sodium or sodium fluoride to the metal just before casting. This process of modification has not yet been applied commercially to other alloys, but the possibility has been demonstrated. The aluminium silicon alloys are very resistant to corrosion both in moist air and in contact with sea-water. Aluminium silicon alloys have a wide application. They are used for sliding panel-doors on railway coaches, and for a variety of die-castings in the automobile and aircraft industries.

Aluminium copper alloys containing 8 to 12% of copper are still used to a large extent. These alloys have a tensile strength of 9 to 12 tons per sq. in., which may be increased up to 22 tons per sq. in. by suitable heat-treatment. This process is, however, long, and needs careful handling.

The best general properties are provided by the 8% copper alloy, which is used in the automobile industry for induction pipes, oil-cans, and various housing castings. The addition of small quantities of tin or zinc (1 to 2%) with a view to improving casting qualities has been employed, but appears to have a detrimental effect on strength at high temperatures.

ALLOYS OF MAGNESIUM.

Magnesium and its alloys, although they have not so wide an application as aluminium and its alloys, are rapidly coming into more favour. Magnesium itself is two-thirds lighter than aluminium, and were it not for the existence of the aluminium-silicon alloys, this alone would favour its more extensive use. As it is, until the price of magnesium comes down, magnesium and its alloys will have difficulty in competing with the aluminium light alloys. Although magnesium alloys show better figures on a strength/weight basis, no magnesium alloys are known whose mechanical properties are quite so good as those of heat-treated duralumin and "Y" alloy. Only where a given volume is essential, rather than a minimum section, have the magnesium alloys the advantage, and therefore their widest application is, as would be expected, in the aircraft industries, where minimum cost is not a primary consideration. Magnesium alloys were used by the Germans during the war for Zeppelin construction, and since then have been developed extensively in that country for aeroplanes and dirigibles. Elsewhere the availability of duralumin and similar aluminium alloys have rather prejudiced progress in their development and extended use.

Pure magnesium can be cast and rolled, but has not had much use commercially owing to its very rapid corrosion in moist atmospheres. Recent research in methods of eliminating traces of impurities, such as chloride, etc., has, however, considerably improved the corrosive properties of both magnesium and magnesium alloys, and made them more comparable in this respect with the aluminium alloys. In the sand-cast condition, magnesium has a tensile strength of 6 tons per sq. in., with an elongation of 6%. In the form of rolled sheets, the tensile strength is 12 tons per sq. in., and an elongation of 5%. These figures are superior to those for aluminium, but the elastic limit of both magnesium and magnesium alloys is low, which is undesirable for most engineering purposes. Magnesium is not so good an electrical or thermal conductor as aluminium, and, even when allowance is made for the difference in specific gravity, cannot compete favourably.

Magnesium alloys have been developed in Germany, America, and to a large extent in recent years in our own country. Those developed in Germany under the rather wide term, "elektron," have zinc and/or aluminium as their predominant alloying element. The published information on these alloys is scanty. Modern "elektron" alloys contain a small percentage of manganese, which considerably increases their resistance to corrosion without altering their mechanical properties.

"ELEKTRON" ALLOYS.

An "elektron" alloy containing 4·3% of zinc and 0·8% of iron has a tensile strength of 9 tons per sq. in., and an elongation of 5% as cast, and in the forged and heat-treated condition the tensile strength may be 23 tons per sq. in., with an elongation of 18%. Another "elektron" alloy containing 6·25% aluminium, 1% zinc, and 0·35% manganese has in the forged condition, a tensile strength of 20 to 24 tons per sq. in., and an elongation of 10 to 12%.

Recently the German manufacturers of elektron have produced a magnesium silicon aluminium alloy which is being used for pistons and other automobile parts. This alloy has a high resistance to corrosion.

In America magnesium aluminium alloys have been developed under the name of "Dow Metals," and have been used mainly for pistons and connecting rods for automobile, aeroplane, and motor-boat engines. The manufacturers claim that these alloys are the lightest materials available, and also that they differ from aluminium alloys in that there is no permanent growth or set at the working temperature of the internal combustion engine. The percentage of aluminium varies from 2 to 8·5, according as to whether a casting or forging alloy is required, and whether ductility, strength, or resistance to corrosion is of chief importance. Manganese is added to improve resistance to corrosion, but its percentage must be kept within a narrow critical range or its presence is harmful rather than beneficial. An alloy containing 6·0% of aluminium, 0·25% of manganese, has a tensile strength, as cast, of 12·5 tons per sq. in., and an elongation of 7%. The tensile strength and ductility are increased by heat treatment.

RECENT DEVELOPMENTS.

In this country alloys of the magnesium-aluminium-zinc type have made rapid advances during the last few years. Forgings can now be made, in addition to castings and extruded bars, and the physical properties are very good. In the stamped or forged condition the tensile strength is 17 to 19 tons per sq. in., with an elongation of 12 to 15%. The rolled strip or sheet can be obtained with 16 to 18 tons per sq. in. and 10 to 16% elongation for the soft variety, and 20 to 22 tons per sq. in. tensile strength and 2 to 3% elongation for the hard variety. The extruded bar has better properties, and gives a tensile strength of 20 to 22 tons per sq. in. and 10 to 12% elongation. For aircraft work, including propellers, crankcases, etc., these magnesium alloys are rapidly finding wider applications.

The most important contributions to the developments of light alloys during the last few years have been not so much the discovery of new alloys, but rather improved methods of melting and casting, heat treatment and modification, and, a problem not yet discussed in this article, protection.

The production of sound castings has been one of the greatest problems in the history of light alloys. Valuable work at the National Physical Laboratory has enabled the foundryman to produce aluminium alloy castings free from

(*Continued on page* 64.)

Some Structural Characteristics of High Chromium Irons and Steels

Part I.

By J. H. G. MONYPENNY, F.INST.P.,
Messrs. Brown Bayleys Steel Works, Ltd., Sheffield.

THE effects produced on the structure and properties of steel by the addition of chromium, up to about 12 or 13%, are fairly well known; they may be briefly summarised as follows:—The addition of the chromium lowers the carbon content of the microstructural constituent pearlite; raises the temperature of the Ac. 1 point; retards very markedly the solution and diffusion of the carbon in the heated steel; and induces in the latter the property of air-hardening. The effects as regards the first three actions are summarised in Fig. 1, which indicates diagrammatically the changes produced in the portion of the iron-carbon diagram illustrated by the addition of about 12% chromium.

From the data plotted in this diagram, one would expect that such high chromium steels, when heated, would behave broadly in the same manner as ordinary steels. With the exception of one notable feature they do so, providing the chromium content does not exceed about 12 or 14%. On heating the high chromium steels, the pearlite they contain transforms at the Ac. 1 point to austenite, and the latter then proceeds to dissolve any excess carbide or ferrite in the steel, producing eventually

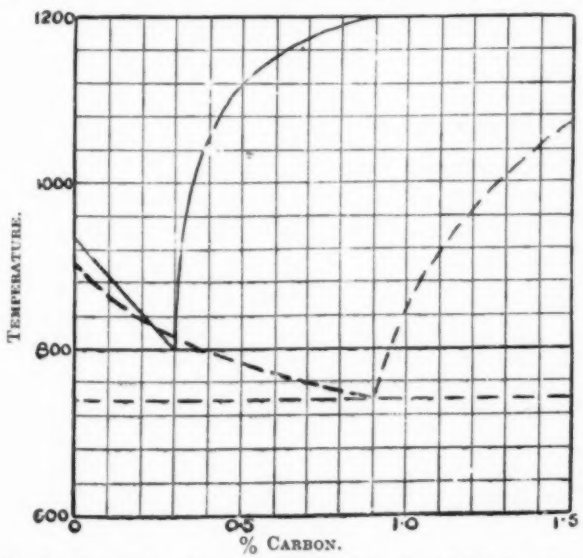


Fig. 1.—Iron-carbon diagram as modified by about 12% chromium.

a structure consisting entirely of austenite. The exception is in respect of the carbide of the pearlite: instead of dissolving rapidly and entirely at the Ac. 1 point, as in ordinary carbon steels, the carbide of these chromium steels dissolves very sluggishly, so that even in hypoeutectoid material free carbide is likely to be present in samples quenched 100° to 150° C. above the Ac. 1 point. As a result of this sluggishness in the solution of the pearlite carbide, the solution of the excess carbide in steels containing more than about 0·3% carbon, does not commence until about 950° C., as indicated in Fig. 1. Obviously, the line in Fig. 1 marking the position of Ac. 1 in these steels, represents merely the beginning of this change, and not, as in ordinary steels, the whole of it.

Due to these characteristics, the high chromium steels in this category are susceptible to heat-treatment processes in much the same way as carbon steels and ordinary structural alloy steels, and they give, after suitable treatment, mechanical properties similar to those of high-tensile alloy steels. Material of this type constituted the original "stainless" steels and irons, the development of which took place rapidly after the Great War. For some purposes, however, a higher chromium content appeared to be desirable on the grounds of resistance to corrosion, but experiments in this direction showed that when the chromium content rose above about 14%, the carbon content being 0·3% or less, the properties of the material changed markedly in certain directions, the most important having reference to hardening capacity. The latter property diminishes so markedly with increasing chromium content that eventually no noticeable increase in hardness is obtainable by quenching the steel from any available temperature. The lower the carbon content, the more effective is the chromium in this respect; thus, in Fig. 2 are plotted the Brinell hardness numbers obtained from small samples of steels, all containing about 0·10% carbon but different amounts of chromium, after quenching in water from the temperatures indicated; curves A to C in Fig. 3 similarly relate to steels containing approximately 0·20% carbon.

A striking feature of the curves in Fig. 2 is that in all cases the Brinell numbers rise to a maximum and then

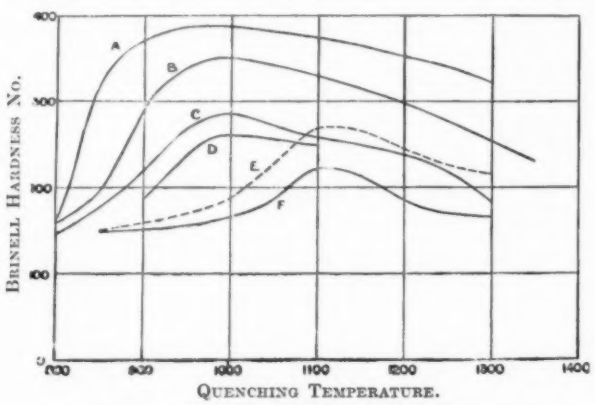


Fig. 2.—Quenching Tests on Stainless Irons.

Curve	*A*	*B*	*C*	*D*	*E*	*F*
Carbon %	0·09	0·08	0·10	0·09	0·13	0·10
Chromium %	12·3	14·0	15·3	16·0	17·2	20·4

fall again as higher and higher quenching temperatures are used. This fall in hardness is not due to the retention of austenite in the quenched sample, as frequently occurs with steels of much higher carbon content—*e.g.*, curve E, Fig. 3,—but to the progressive separation of ferrite. Sample A, containing 12·3% chromium, consisted entirely of martensite when quenched from 950° C. (the ferrite dissolving gradually between 800° C. and this temperature), and this condition persisted up to over 1,150° C. The sample quenched from 1,200° C. contained a small quantity of ferrite, and the amount increased as the quenching temperature rose to 1,250° and to 1,300° C.

The 14% chromium iron, curve B, showed a similar solution and reprecipitation of ferrite, but with a notable difference. There was the same gradual solution of the ferrite as the temperature rose above 800° C., but only up to a certain point; in no case was a structure perfectly

free from ferrite produced. The minimum amount of this constituent was found in the samples quenched between 1,000° C. and 1,050° C. There was noticeably more in that quenched at 1,100° C. and the amount increased steadily with still higher quenching temperatures. The sequence of structural changes is illustrated in Figs. 4 to 8. These also show a further peculiarity of high chromium irons. As the quenching temperature rises to 1,250°—1,300° C. there is a gradual grain growth, such as might have been predicted (one should note in this connection the higher magnification of Fig. 4 as compared with the others), but at 1,340° C. the structure becomes excessively coarse, and also different in character from that previously found. The samples used for these experiments were polished and examined on a plane parallel to the length of the bar from which they were cut, and in all the samples quenched below 1,340° C. the banded arrangement of the original rolled bar is quite evident in the structure; this is entirely obliterated in that quenched at 1,340° C., and replaced by an excessively coarse cellular pattern.

Figs. 4 to 8.—Structures of 14% chromium iron after quenching from various temperatures.

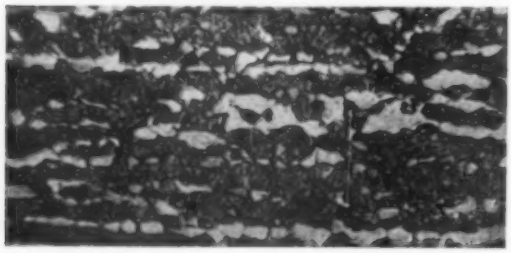


Fig. 4.—W.Q. 950° C. × 300 diam.

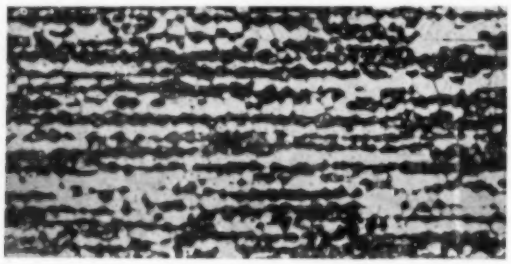


Fig. 6.—W.Q. 1,150° C. × 100 diam.

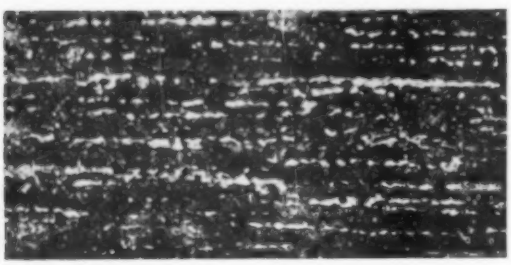


Fig. 5.—W.Q. 1,050° C. × 100 diam.

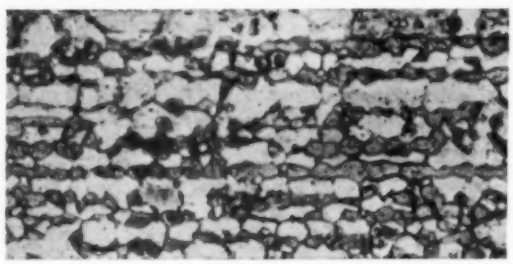


Fig. 7.—W.Q. 1,250° C. × 100 diam.

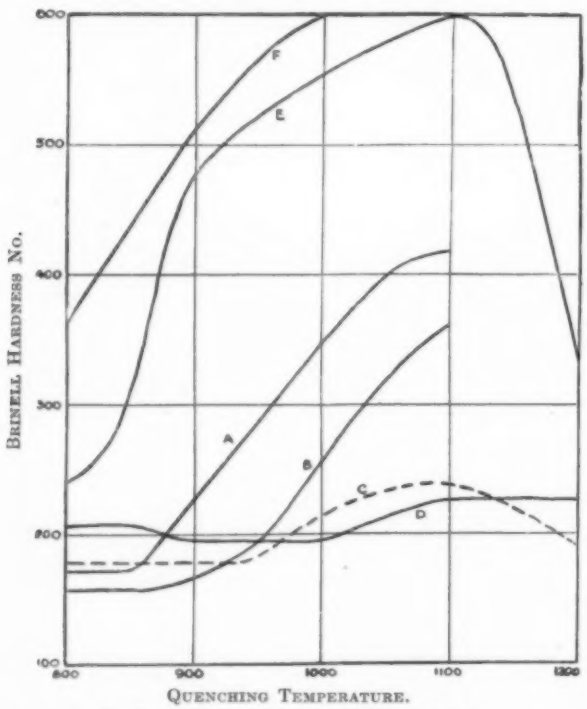


Fig. 3.—Quenching Tests on Stainless Steels.

Curve	*A*	*B*	*C*	*D*	*E*	*F*
Carbon % ...	0·17	0·17	0·21	0·42	0·87	1·90
Chromium % .	15·9	17·1	20·1	25·0	17·6	27·5

One may observe the production of this coarse structure in stainless irons very conveniently by taper-heating a short bar of the material, so that one end is raised to its melting point, while the other remains below about 700° C., and then quenching it out in water. A bar about ½ in. square is a convenient size, and, after quenching, one face is machined or well ground to remove oxidation effects, and then polished and etched. Fig. 9 represents at 15 diameters the structure of such a bar at a point near the melted end, and shows that the production of the coarse structure occurs quite suddenly, as though some internal change such as occurs at Ac. 1 had taken place in the material.

If the cooler end of the bar did not reach a higher temperature than about 700° C. before quenching, one can trace along its etched surface the whole sequence of changes occurring as the steel is reheated to and quenched from higher and higher temperatures. Thus, in the bar from which Fig. 9 was taken, and which contained 15·0% chromium, one could see the production of martensite at Ac. 1, and the gradual solution of the ferrite as the temperature rose above this, giving eventually a structure

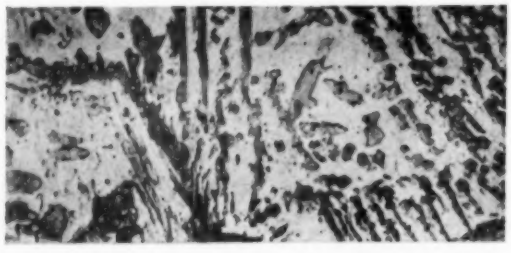


Fig. 8.—W.Q. 1,340° C. × 100 diam.

similar to Fig. 10. Still nearer the hotter end of the bar, the progressive coarsening of the grain size could be observed and also a gradual increase in the amount of the ferrite; then came the abrupt change in structure shown in Fig. 9, and, finally, the continuance of this coarse angular pattern up to the melted end of the bar.

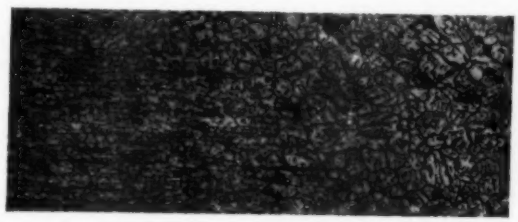


Fig. 9.—15% chromium iron. Taper-heated sample, structure near melted end, × 15 diam.

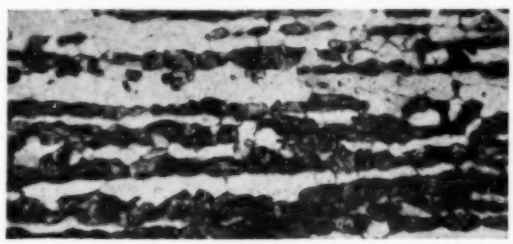


Fig. 10.—15·5% chromium, 0·10% carbon. W.Q. 1,000° C. × 300 diam.

It may be noted that a similar coarse structure was obtained near the melted end of a bar of stainless iron containing 12·5% chromium when treated in the manner described above; on the other hand, neither the coarse structure nor the reprecipitation of ferrite at high temperatures was observed when material containing 10% chromium was tested in this manner.

A sequence of structural changes like those described for the 14% chromium material is obtained from

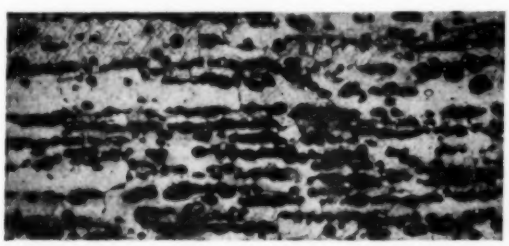


Fig. 11.—17·2% chromium, 0.13% carbon. W.Q. 1,100° C. × 100 diam.

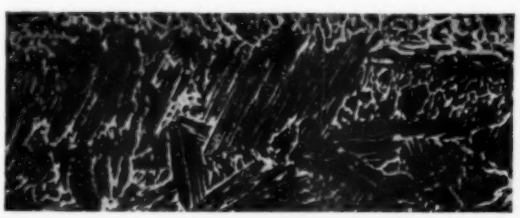


Fig. 12.—11·7% chromium, 0·07% carbon. As cast × 50 diam.

irons containing still more chromium, except that these always contain considerable amounts of ferrite, no matter from what temperature they are quenched. Also, the amount of ferrite produced after similar treatment is greater the higher the chromium content. For example, Figs. 10 and 11 refer to irons containing 15·5 and 17·2% chromium respectively, quenched in each case from the temperature giving maximum martensite content. A comparison of these with Fig. 5 illustrates this effect of chromium; a further indication of it may be seen in Figs. 12, 13, and 14, representing the structure of various stainless irons as cast. Here the amount of ferrite is considerable greater, for similar chromium contents, than in the photographs just described—and for reasons which will be evident from the structural changes which have been considered; but again the amount increases as the chromium content rises.

A further peculiarity of the curves plotted in Fig. 2 may also be noticed. Up to 16% chromium (curves A—D) maximum hardness is obtained on quenching from a temperature in the neighbourhood of 1,000° C. The higher chromium irons, containing 17·2% and 20·4%, require, however, a temperature of 1,100—1,150° C. The significance of the sudden change occurring between 16% and 17·2% chromium will be referred to later.

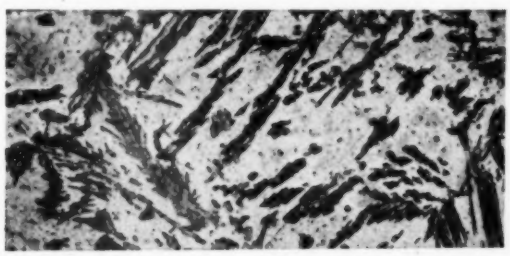


Fig. 13.—16·0% chromium, 0·09% carbon. As cast × 20 diam.

The cause of the structural changes described in the preceding paragraphs lies in the effect which chromium has on the temperatures at which the A 3 and A 4 changes occur in iron. It lowers very rapidly the temperature at which γ–iron changes to δ–iron. The effect on the α–γ transition is not so marked; probably additions of chromium up to 7 or 8% lower this temperature to some extent, but with still more chromium it rises at an increasing rate, with the result that in a perfectly carbonless iron-chromium

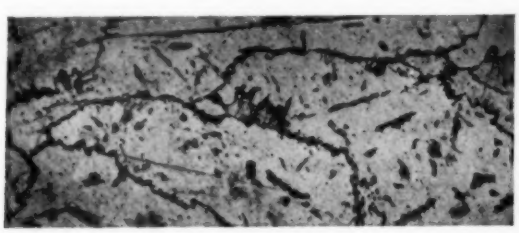


Fig. 14.—20·4% chromium, 0·10% carbon. As cast × 20 diam.

alloy, containing about 14 or 15% of the latter metal, the temperatures at which A 3 and A 4 occur have reached the same value, and γ–iron ceases to exist. As α–iron and δ–iron are structurally identical, no internal change occurs on heating and cooling such an alloy.

The exact chromium content needed to produce this effect has not yet been determined. Maurer,* who investigated a series of iron-chromium alloys containing not more than 0·03% carbon, placed the disappearance of γ–iron at about 16% chromium. E. C. Bain,† however, considers that less chromium than this is required, and places the limit at about 13%. More recently, Oberhoffer and Kreutzer‡ have shown, by X-ray examination of the crystal structure, that γ–iron is produced up to about 15% chromium, but not beyond that amount. Hence, in the

* Ueber den inneren Aufbau der Chromstahle. "Stahl und Eisen," 1928, p. 999.
† "X-Rays and the Constituents of Stainless Steel." Trans. A.S.S.T., xiv. (1928), 27.
‡ "Stahl und Eisen," xlix. (1929), pp. 189/190.

present state of knowledge, a mean value of 14 to 15% would appear to be reasonably correct, and this value has been adopted in Fig. 15, which represents diagrammatically the effect of chromium on the A 3 and A 4 change points of iron.

If, however, the iron-chromium alloys contain carbon as well, even in small amounts, the action of the chromium in preventing the formation of γ-iron is delayed;

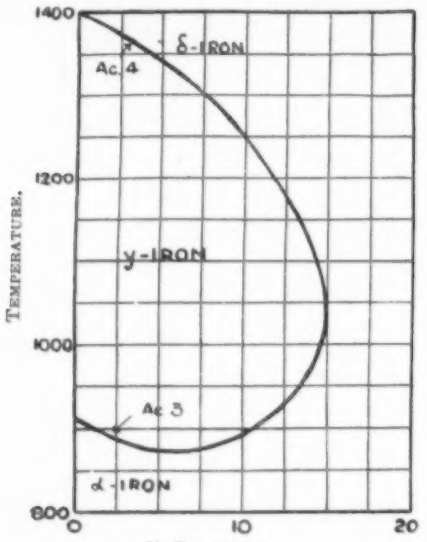


Fig. 15.—Effect of chromium on A 3 and A 4.

hence in such alloys, containing over 15% chromium, a certain amount of austenite is formed, depending on the actual carbon content, and the alloy hardens to a corresponding extent, which, with any given carbon content, diminishes as the amount of chromium present steadily

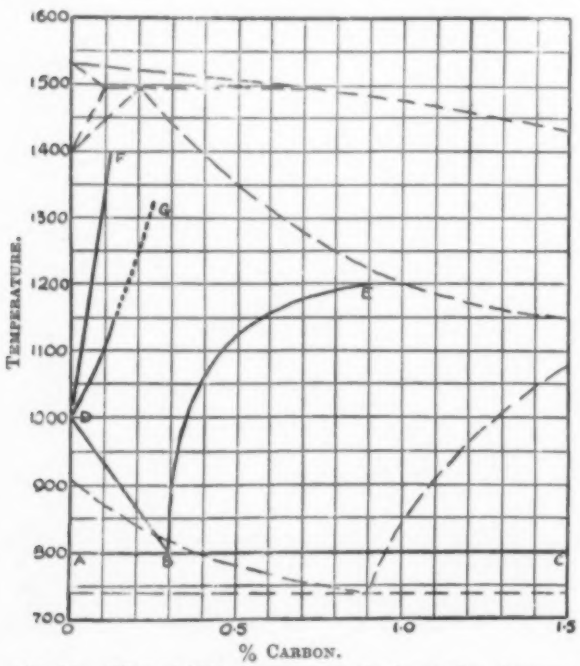


Fig. 16.—Effect of 15% chromium on the iron-carbon diagram.

rises. Similarly, the hardening capacity of alloys containing equal amounts of chromium increases with their carbon content. This may be observed by noting the curves in Figs. 2 and 3, and comparing those relating to irons and steels of like carbon or chromium content.

The structural changes in steels containing about 15% chromium may be indicated in a qualitative, rather than a quantitative, manner by Fig. 16. The thin broken lines in this diagram represent part of the iron-carbon equilibrium diagram, including the δ-iron range; the thick lines show the corresponding changes in the chromium steels. Ac. 1 or, rather, its beginning, is represented by A B C, and Ac. 3 by B D, while B E indicates the solubility of the excess carbide in the higher carbon steels. This part of the diagram is similar to that in Fig. 1. δ-iron commences to separate from the austenite along D G; above D F the mass consists entirely of δ-iron. The outstanding feature of the diagram is the enormous increase in the range of existence of δ-iron, which is brought about by the presence of 14—15% chromium in the steel. Following what has been said in the preceding paragraphs, the diagram indicates that the carbonless alloy possesses no γ-iron range at all, but that the addition of carbon results in the formation of austenite. With only about 0·1% carbon, such as is present in a typical "stainless" iron, the range of temperature in which austenite exists is not very wide, and at about 1,100° C. δ-iron begins to separate out. At 1,300°—1,350° C. the whole mass consists of a solution of carbon in δ-iron. It will be recalled that in this range of temperature the structure of quenched samples became suddenly very coarse (see Figs. 7 and 8). It is very probable that the martensite visible in Fig. 8 comes from austenite which has separated out from the δ-iron during quenching, despite the rapidity of the latter; the mode of occurrence of the austenite, as a network round the ferrite grains and as barbs crossing the latter, strongly suggests this mode of formation. Probably the same cause, the impossibility of attaining a sufficiently rapid rate of quenching, and also the sluggishness of the diffusion of carbon in high chromium steels, accounts for the presence of ferrite in the samples of the 14% chromium iron quenched at about 1,000° C. (see Fig. 5).

(*To be continued.*)

LIGHT ALLOYS IN ENGINEERING

(*Continued from page* 60.)

the "pinholes" and "blowholes" so fatal in earlier days. The difficulties of casting magnesium have also been overcome by using appropriate fluxes, and sound magnesium alloy castings are now available.

"PROTECTIVE TREATMENTS."

Methods of heat treatment and modification have already been discussed. The tendency of both magnesium and aluminium to corrode may now be inhibited, in addition to the process of adding manganese to the alloy by what is termed "protective treatments." The most important of these is that of anodic protection followed by subsequent application of a grease, such as lanoline, due to Bengough and Stewart. This process, however, can only be applied to aluminium and aluminium alloys. The finished articles are made the anode in a 3% aqueous solution of chromic acid or its equivalent salt at a temperature of 40° C. The voltage is raised from 0 to 50 volts over a period of one hour, when a dense resistant coating of oxide is formed which is an excellent protection against further corrosion. This protection is further improved by the application of grease or paint. Alloys so treated have good resistance to sea-water corrosion, and this process ought to have more universal use than it has.

Magnesium alloys cannot be treated in this way, but a satisfactory process has been developed by which these alloys may be given a protective coat of chromate by dipping in a series of special pickling baths. This film is not so resistant to corrosion as the oxide film of the anodic process.

The Welding of Metals, with Special Reference to Flux-coated Electrodes

By EDWARD DACRE LACY

Better results are claimed for Flux-coated Electrodes than can be obtained with bare or coated welding wire, when their special properties become more familiar.

WELDING, without doubt, has now become one of the most important and widely used of all metallurgical processes, and, as results of experiments and investigations are tabulated from day to day, the practice grows in almost every industry.

To the lay mind, welding seems to be a very simple process—merely the fusion of two metals, but those who have had experience with this process know that it is by no means an easy matter to make any form of welded joint to give the best possible result. Even experienced welders are sometimes puzzled by the kind of results that they obtain, owing to the fact that some factor which is outside their control creeps in and upsets their calculations.

There are many things which affect the making of a good weld. Therefore it is not surprising that results are variable, making it essential that the subject should be studied in a scientific fashion in order to guard against the making of bad welds.

Omitting physical deformation, the most common form of defects to be found in welding are low tensile strength and poor elongation. These defects cause either brittleness or indifferent bending qualities of the joint, and offer little resistance to fracture by shock.

Low elongation is very visible when joints are being tested for tensile strength in the testing machine, as the amount of plastic stretch at the joint is usually very small. In spite of the above-mentioned disadvantages, it must not be thought that any of the various systems of welding which are used are, in the main, faulty; each process has its place in production and repair work.

DIFFERENT WELDING PROCESSES.

The repair of metal articles in everyday use in industry by welding has now become an accepted method. But it is not always realised that there are a good number of different welding processes that can be used. However, those chiefly in use to-day are the oxy-acetylene method and the electric-arc process.

The oxy-acetylene blowpipe, which has been in constant use for over twenty years, is limited as to the work which can be accomplished by it, but, in spite of the disability, and considering the fact that electric-arc welding has, in a number of instances, taken the place of its forerunner, oxy-acetylene welding will never be entirely displaced.

Electric arc welding, by means of metal electrodes, has now been known for over sixteen years; alloy metals can be effectively welded by use of metal electrodes which will produce in the weld metal of the same composition, and twenty-three different kinds of electrodes are now on the market.

In the welding of alloys of all descriptions many problems have had to be solved. It is not so very long ago—a mere matter of fifteen years or so—that welders were compelled to admit that welding of any alloy metals was beyond them. Those were the days when a very fair job could be made with the blowpipe, using what was termed "Swedish iron."

The coming of the electric arc has altered the position very materially. The intense heat of the arc has simplified much of the work, but it has created problems of its own, since the intense heat has a way of creating fresh compounds with, from the welder's point of view, very inconvenient results.

WELDING ALLOY STEELS.

As a matter of fact, successful welding of alloy steels became a *fait accompli* towards the end of the world war, and a strength of 100% can be guaranteed in practically every steel alloy available. Similar strength can also be obtained in many non-ferrous alloys. It is interesting to note that it is very probable that an aluminium electrode will soon be placed on the market. Experiments have for some time been carried out for placing this electrode on the market for commercial use.

It is now seven years since stainless steel was first satisfactorily welded, and since that date stainless steel electrodes which give entirely satisfactory results have been supplied.

From the very first, the materials to form the particular alloy required were mainly incorporated in the flux coating, but the necessary nickel was added to the core wire by electro-deposition.

It is essential when adding nickel that the coating should be a particularly good one, in order that proper combination may occur in the electric arc. An indifferent coating of nickel may be burnt by the electric arc and dissipated in the air.

The past two or three years have shown very considerable increases in the uses to which stainless steels have been put. The original stainless steel, composed of varying percentages of chromium and iron, while satisfactory for many purposes, was found to be unsatisfactory when used for the manufacture of chemical vessels, with the result that many other alloys have been put upon the market, each of which shows certain advantages, but all again presenting problems in the welding of them.

Those firms who specialise in the manufacture of stainless steels have been pleased to confer with the manufacturers of electrodes regarding the welding of such steels, and in each case it has been possible for special material to be made which gives entirely satisfactory results, and, at the present time, no fewer than eighteen different types of corrosion and heat-resisting steel electrodes are manufactured for use with steels manufactured by the best-known firms in the British steel industry, such as Thos. Firth's "Staybrite," Brown Bayley's "Anka," Hadfield's corrosion- and heat-resisting steels, *Vickers-Armstrong's "Vikro," and *Cammell Laird's "Cameoy," to name only a few.

In every case laboratory tests proved that the analysis of the metal deposited from these electrodes was within the steel-makers' specification. Other electrodes are made for the welding of monel metal and for steel manufactured by foreign concerns, such as Krupps. In fact, it is now possible to manufacture special electrodes for any proprietary makes of steels, provided that the formula of such steel is known.

Electrodes with metallic inclusions with the flux coating are also obtainable for depositing high-carbon steel, self-hardening steel giving a dead hard surface, and a high-speed steel for tipping shanks of mild steel.

ELECTRIC WELDING FOR PRESSURE WORK.

It is a well-known fact that electric welding is now extensively used in the construction of boilers, and more particularly, perhaps, in repair work to these and other forms of pressure vessels. The steel used in connection with boiler construction and similar classes of work is of 28 to 32 tons tensile. It is, therefore, only reasonable to expect that welded joints for such work should be capable of withstanding similar stresses without undue reinforcing of the plate thickness. The reinforcing of welded joints in order to secure higher tensile strength is dangerous, inasmuch as stresses are set up in working, due to unequal expansion and contraction through the presence of varying thicknesses.

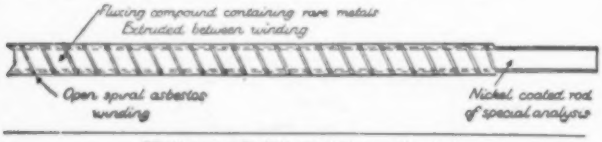
It is desirable, therefore, to obtain a weld giving a strength equal to that of the plate employed, and at the same time retaining equal thicknesses. Ordinary flux-coated electrodes will not give the desired result, owing to the fact that, apart from reducing oxidation in the weld, such electrodes cannot deposit a metal of greater tensility than that of the wire employed. Such wire rarely exceeds 26 tons per square inch, and therefore a 100% weld made with these electrodes will only produce a weld of similar strength.

To overcome this difficulty, electrodes known as "A.W.P.," Special "A" and Special Tensile "B," should be used, as not only do they provide the necessary flux to produce a weld free from porosity and oxidation, but by the inclusion of special ingredients in the flux coating, ensure securing a weld strength of 30 to 35 tons per sq. in.

It is interesting to note that Lloyd's Register of Shipping, British Corporation and Bureau Veritas, in order to assist firms in the shipbuilding industry who desire to employ electric arc welding, have granted their approval to the use of electrodes produced by certain manufacturers for use in ship construction and repair work.

WELDING TESTS.

To obtain the approval of each of the above-mentioned societies, each electrode had to undergo an exhaustive series of tests, including ultimate strength, modulus elasticity, alternating stresses, cold bending, impact tests, crushing tests, and also mechanical and microscopic analyses.


Fluxing compound containing rare metals
Extruded between winding
Open spiral asbestos winding
Nickel coated rod of special analysis

*Both now "English Steel Corporation Ltd.

Since the advent of metal arc welding, great advancement has been made in this branch of the foundry business. In the old days welding had got into a state of ill-repute amongst consulting engineers, owing to the poor quality metal put down by the carbon-arc process. To obtain the best results from electric-arc welding, a certain amount of onus must be placed upon the operator, but it is more important that the best electrode should be used, and that choice should be made irrespective of price.

Many important tests have been carried out by the chief manufacturers of electrodes, and until such tests have been witnessed first-hand by engineers, they will, unfortunately, remain sceptical to this process. If a definite standard of welding can be obtained, and certificates issued by some engineering body of standing, the elimination of the bad element in welding would be for the advancement not only of the process, but of British industry.

Ever since the advent of flux-coated electrodes, a great controversy has arisen between the adherents of the covered electrodes and those who still advocate the use of bare wire.

It is a known fact that the U.S.A. is the home of bare-wire welding, but it comes as a pleasure to manufacturers of English electrodes to note that increasing use of flux-coated electrodes is now being made in that country, and it is evident that the advantages claimed for such are now being realised by engineers and others.

PROGRESS OF FLUX-COATED ELECTRODES.

The following extracts from papers read by prominent American welding engineers illustrate the progress that is now being made in that country regarding the flux-covered electrode :—

"It is well known that when welding with bare wire, of any ferrous composition whatever, the resultant weld is composed of pure iron, because the high temperature of the arc drives off the other ingredients as gases. It is the function of the flux to prevent this state of affairs, and it does prevent it in a most effective way. As a matter of fact, modern developments in flux coatings have made it possible to lay down deposited metal of a predetermined composition, so that it is now possible to duplicate in the weld such metals as manganese, high-carbon steel, and other steels of very special qualities, impossible to deposit with the bare-wire electrode, no matter what its composition."

"Tests showed that the properties of ductility and elongation were increased by flux-coated electrodes as the result of cold-bend test, at no sacrifice of strength, because in each case the test piece broke outside the weld. With no other system was this true in those tests."

"Fluxes are also useful in ridding the weld of such undesirable impurities as sulphur and phosphorus, both of which tend to produce a hard, brittle mass of metal in the weld."

"It will be seen from this that for a multitude of uses there is no satisfactory substitute for the flux-covered electrode in arc welding. The flux coating not only aids in many special ways, but actually lowers the cost of the weld by its capabilities of greater speed of deposition and surer production of consistently desirable results."

"By comparing the weight of metal before and after welding, it has been shown that 20% of a bare-wire electrode is lost during the welding operation. With a flux-coated electrode this loss is less than 5%, indicating that more metal actually goes into the weld when using the coated electrode."

"In the desire to produce satisfactory welding results, it is not uncommon to find that welding materials of the same chemical composition as the metal to be welded are often in use. In the melting of the rod, however, during the welding operation, there is a considerable loss of the various elements of which the rod is composed, and experiments show that there is not a sufficient amount of these special ingredients in the deposit secured to be of any practical value."

The above expressions being opinions of recognised welding experts in America, are sufficiently forceful to condemn the theory of bare-wire welding. The use of bare wire is a retrograde step in welding practice, and should not in any circumstances be considered.

Again, until recently, bare wire was almost exclusively used in Germany, and we reprint here extracts from a paper entitled "The Progress in Electric-Arc Welding and the Advantage of Asbestos-Wound Electrodes," read by Dr. Neese, of Essen, at a meeting of the V.D.I. Department for Welding Practice at Hamburg recently :—

"I previously mentioned that coated electrodes on the market up to that time did not, in my opinion, promise an improvement in the strength of the weld, but that in some difficult cases they facilitated the operation, and in this way effected improvement. Tests carried out by the Research Society during the last twelve months have confirmed this opinion.

"It seems to me somewhat different with some asbestos-wound electrodes of English origin. The main object of English firms is to endeavour to obtain a weld of improved quality, without considering the relatively high extra cost of the electrodes. The leading thought is absolutely correct.

"The engineering industry uses an unlimited number of different materials, all of which belong to the group called iron, but for all these materials, with very few exceptions, the same class of welding wire is used for welding. This principle is wrong ; the wire should be selected according to the nature of the material to be welded, as is being done by an English concern. As the name of 'alloy welding' expresses, the fused electrodes are alloyed. The wire is bound with asbestos yarn, and the intermediate spaces are filled with some material which, in addition to developing slag, gives the deposited metal certain qualities, such as varying hardness, easy flow, resistance to the effects of rust or acid, and even the qualities of high-speed steel.

"With the latter type of electrode a deposit on a piece of ordinary mild steel makes a first-class tool steel, which hardens in air or oil. I have used several cutting tools of such material in my own works for three or four weeks, and can say that they are equal to solid high-speed steel tools.

ALLOYING MATERIALS IN ELECTRODE COATING.

"The electrodes are manufactured for various degrees of tensile strength, and this is obtained through the alloying material, which is contained in the electrode coating. The large quantity of slag which develops is so composed that it does not adhere to the weld, but it completely covers it. Thus, the arc works practically air-tight, and is hardly visible. The deposit itself flows easily, burns deep, looks as smooth as autogenous welding, and possesses strength and tension. For the cold welding of grey castings especially, the use of these electrodes offers great advantages.

"When the special properties of these electrodes have been got used to, better results can be obtained than with the bare or coated welding wire.

"In nearly every case, wearing parts are, or should be, made from steel. I have in mind in this connection such parts as rails and crossings, clutches, pins, guides, and rollers, cutters, chains, and similar parts used in connection with the railway, rolling-mill, mining, cement, and other industries. For a long time it has been the practice to build up worn parts without considering the quality of the metal, and it is generally looked upon as a simple job, which rarely warrants the trouble of selecting electrodes. Some firms have tried a hard wire, but usually with poor results, as this wire was not found to be harder after the welding than ordinary wire. It also showed many blow-holes, was spongy, and made a very inferior binding medium.

"The necessity for economy has of late led to further experiments, and I am glad to say that good results have been obtained.

"By continuous research, materials of various degrees of hardness have been produced, so that a Brinell hardness of 100 to 400 (and 48 to 140 kilog.) can be obtained, provided that the proper method of welding is used. The weld itself can be said to be perfect ; the penetration is good ; the deposit shows fewer blow-holes than does ordinary bare wire ; and hardness is uniform. It is important to note that this weld will wear even better than material of this hardness is expected to do. With proper selection and application of the electrode welded parts have given 70% longer wear than unwelded parts of the same quality.

"In connection with a certain tramway line, it has been observed that rebuilt rails, after twelve months' service, did not show any wear at all, in spite of heavy traffic, whilst new rails, after two years' service, were completely worn."

REPAIRS BY WELDING.

Welding repair work is now used in practically every industry, and perhaps by none more so than by motor manufacturers, both makers of private and commercial vehicles. It was only a few weeks ago that there appeared in the press a notice to the effect that Mr. Ford had ordered a number of electric-arc welding machines for the manufacture of the Ford cars, and in this country electric-arc welding is now being used extensively by the chief motor manufacturers.

In connection with the repair of motor-car and commercial vehicle chassis, it may be of interest to detail some of the repairs that can be carried out by this process :—

> Repair of fractured spokes, rims, cast-steel axle-cases, repairs to gearboxes, crankcases, and cylinders ; and welding is also extensively used in the repair of fractured frames and frame members, in repairing front axles, and it is no uncommon thing to read of the welding of crankshafts and camshafts.

In addition to the motor industry, other transport concerns have, within the last few years, extensively increased their use of welding. Railway companies, who cannot afford to take risks in connection with the upkeep of their rolling-stock, have now introduced electric-arc welding into their repair shops, and a large amount of work of this kind has been carried out by tramway companies, who are able to apply this process to uses which include repairs out on track-wheels and tyres, gear-wheels and shafts, amongst others.

POSSIBILITIES IN SHIPBUILDING.

There is undoubtedly great scope in shipbuilding for the utilisation of electric-arc welding, which has been found suitable for the building of smaller vessels, and can now be extended to vessels of larger size, as experience is gained, and as the processes of electric-arc welding are perfected. Not only for structural purposes, but for the building of boiler, deck, and below-deck machinery this process can be used, and it has now been proved beyond doubt that a welded joint is very much stronger than a riveted one.

In the actual construction of a mercantile vessel, electric-arc welding can be used in many different connections. For instance, in building-up corner and angle bars, this process is cheaper than forging them. Bolts can be welded on steel plating for deck plank-fastenings, thereby obviating the necessity of piercing the decks and possible damage to fittings below where fitting-out work is well advanced. Further, in this connection, where water-tight compartments have already been water-tested, welding can be used instead of drilling, riveting, and caulking, and can be profitably used, as the cost of a re-test of compartments would not be incurred. Welding can also be used in the manufacture of oil and water tanks for use on board ship. In building-up pipe connections for pumping and draining systems, electric welding is of great assistance. Pipes with flanges loosely attached can be put into position temporarily, and the flanges and pipes can be set to correct positions and levels, and just caught by electric welding, then removed

and the welding completed. In many cases electric welding can be used in awkward corners where there is not sufficient space to rivet. Ventilation trunks and deck coamings can be rolled up or bent to shape and welded more cheaply than by riveting.

USES IN SHIPBUILDING.

Electric welding can be used for the following :—Angle-lugs for cabin fittings, carrier-plates for electric cables, lugs on deck for guard stanchions, lugs for steel lining in all fittings upon which life does not depend.

In repair work electric-welding has been used extensively for some years, and in addition to those cases which have been described above, applying to shipbuilding, welding can be employed very largely in alteration work, to avoid the necessity of lifting large pieces of machinery to get in new fastenings, and for restoring corrugations of footplates and ladders by means of specially hard electrodes, thereby saving the expense of new footplates and ladder-treads. Again, electric welding can be used for reinforcing deck pipes and hawse pipes when worn thin with the rub of cables, in the repair of small castings, more particularly steel castings, and in connection with the inner bottom plating when it has been worn thin.

The uses to be made of electric-arc welding by the colliery industry are very varied. In cutting machines, pick-holes can be reconditioned, keyways renewed, new ends welded on bars, the sprockets of chain machines built up and new teeth formed in the place of broken teeth in the crown-wheels. Repairs can also be effected to the casings, jib-plates, and main shafts. Other repair services which have been performed include the fitting of new feet on motor casings ; building up crankpins on plunger pumps ; repairing a three-throw pump crankshaft ; building-up bronze impellers for centrifugal pumps, reinforcing worn spindles and the inside of the casings ; rectifying the bore of rope pulleys, and repairing broken flanges ; making-good cracked engine bedplates, pump casings, coal-cutter casings, plummer blocks, etc., and rectifying old teeth and building-up new teeth on spur-wheels and pinions, whether of steel or cast iron.

It will thus be seen there is an almost unlimited scope for the arc welding process in connection with colliery work, and colliery managers and chief engineers might do well to investigate its possibilities with a view not only to cheapen their repairs, but to construct entirely new parts.

Electric-arc welding is also much used abroad for steel constructional work on buildings, but, owing to the conservatism of governing bodies in England, welding in this connection has been unable to make much progress, in spite of the fact that a few years ago several factories were successfully constructed by this means.

However, the advocates of this process look forward to the time when the noise of pneumatic riveters will cease, and buildings will be constructed by means of welding.

Foundry Extensions Increase Output

THE extensions made to the foundry plant of the Chevrolet Motor Company, Michigan, are expected to more than double capacity. It is stated that 1,875 tons of metal have been cast in one day, but a daily melt of 2,200 tons is expected.

The number of cupolas has been increased from 5 to 11, and the number of conveyors for continuous moulding and pouring from 6 to 14. The area of the work has been enlarged to provide additional floor space for the increased production. The layout of the old foundry, according to the *Iron Age*, has been generally followed in the arrangement of the new equipment, but the new portion of the plant has some new and interesting features.

Large production makes possible the provision of a separate moulding unit for each of the more important smaller castings. In the new part of the foundry there are two mould conveyors for pistons, one for clutch housings, one for transmission housings, one for fly-wheels, one for tappets, and two for miscellaneous small castings. Cylinder blocks are made on three of the old conveyors, and cylinder heads on the other three.

The mould conveyors are of the run-around car type. Cast-iron cars on 4 ft. centres support the ends of ship-channel sections, 18 in. wide, which overlap the car, forming a continuous plate type table, which protects the rails and conveyor chain from falling sand and runouts, and makes the table easier running and safer for the workmen. The conveyor is driven by a drop-forged chain suspended from the bottom of the cars, the drive being of the cantilever type.

At the shake-out end the castings and sand are knocked out through a grating on to an apron conveyor. Gases and smoke are drawn away through a hood above the shake-out. The castings and sand are carried upward and discharged from the apron conveyor into a revolving screen located on the foundry floor. This screen is 54 in. in diameter, and 10 ft. 4 in. long over all. The screen itself is a perforated plate 6 ft. long at the centre of the revolving barrel. The screen is set at a slight angle, so that gravity will cause the castings to move slowly through it while it revolves. At the discharge end the castings fall into baskets under an overhead castings conveyor, or, if desired, can be discharged on to a truck.

Each moulding unit has a screen for separating the sand from the castings, and the handling of the castings afterwards is interesting. The castings are carried below the floor, when shaken out, the flasks remaining on the floor ; there is, in consequence, less smoke and heat in the vicinity of the shake-out. The sand shaken from the casting in the revolution of the screen passes through the screen to a belt conveyor beneath, over a magnetic pulley, which removes the iron and is carried to an overhead sand screen. From this screen the sand is discharged into a pug mill, then passes through a conditioner and into a 75-ton storage bin. From this it is fed through cutting feeders on to a belt into a bucket elevator, which discharges it to a flight conveyor for distribution into the moulders' hoppers. Each unit has its own sand conditioning and distribution plant.

In the new core-room 100 tons of core sand is used an hour. In this department are 64 two-rack type oil-fired core ovens, arranged in two batteries, each consisting of 16 ovens, in a row placed back to back with another 16.

The new cupolas are 9½ ft. in diameter, lined down to about 72 in. Three cupolas are always in use, and are operated for nearly 22 hours. Because of the long period of operation, unusually heavy linings are provided in the melting zones.

An overhead crane delivers pig iron and scrap from railroad cars to the charging floor. The charging buckets are placed on an electrically-driven scale-trolley, which is loaded by hand. Five of these trolleys run across the charging floor at right-angles to the row of six cupolas, their tracks being slightly below the charging floor level. Coke and limestone charges are handled on the opposite side of the cupolas.

The plant to cope with so much metal per day must necessarily be of a colossal character, and considerable ingenuity has been displayed in the layout to simplify organisation.

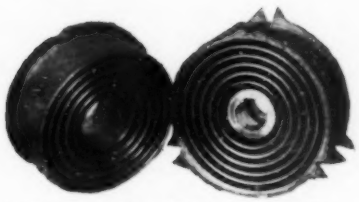


Fig. 2.—Lead Base Alloy, Pressure Die-cast.

Die-Casting Limitations

BY D. RICHARDS.

MUCH has been written on that which has already been accomplished by the various processes of die-casting, particularly in the direction of reduction of cost of production, and also increase of production apart from its scientific aspect. Many otherwise prohibitive propositions have been brought within the range of commercial possibility by the die-casting processes. Very fine limits and finish are obtainable by the pressure process. The finished articles, with threads and holes cast in, and also with steel or brass inserts cast in position, are produced in many instances ready for assembly.

Great credit is due to the pioneers of die-casting for their efforts in overcoming difficulties of a very discouraging nature, and although wonderful progress has been made, the process still has its limitations, which may be set out in the following order :—(*a*) Cost of dies ; (*b*) low tensile strength of the alloys used ; (*c*) porosity ; (*d*) low resistance to pressure ; (*e*) quantities. Under these headings each of the two processes in general demand—*i.e.*, pressure and gravity—will be dealt with separately, each having the same limitations, but in varying degrees.

PRESSURE PROCESS.

(*a*) Owing to the high cost of the dies, which for this process are more in the nature of gauges, due to the line limits guaranteed, the use of pressure die-castings is limited to such quantities as will justify the making of the dies. Were it possible to produce the dies on ordinary engineering lines, the use of die-castings would be almost universal, but, in view of the higher class labour involved, the much-desired "dies nil" on the quotation form remains an impossibility for small quantities.

(*b*) Up to the present time pressure die-castings are only obtainable in comparatively small sizes in low-tensile non-ferrous metals, such as lead, tin, zinc, and aluminium and their alloys, each having its own limitations and uses. The zinc alloys, or white brass, as they are often called, are the most used, being the nearest approach to common brass, for which they are substituted, and for many purposes are quite satisfactory in spite of their very brittle nature. Considerable quantities of zinc-base alloy pressure die-cast cone arms, pedestals, and other parts for gramophones, are made, also many parts for wireless apparatus, gas-meter prepayment mechanisms, temperature indicators for motor-car radiators, gear-wheels for light mechanical movements, numbering wheels, etc. A representative casting of this type is shown in Fig. 1.

Tin and lead and their alloys have their particular uses, the former being in very little demand, due to the high cost of this metal. Fig. 2 illustrates a pair of lead-base alloy die-castings, made by the pressure process. They each have a series of annular rings, each half fitting into the other with a clearance of 0·007 in. between each ring, and having a coarse-pitched thread cast in the centre hole.

Aluminium alloy pressure die-castings have a higher tensile strength, and are more ductile than the zinc alloys. Very fine finish and accuracy are obtainable, but porosity is its main drawback. A very fine example of an aluminium alloy pressure die-cast vacuum-cleaner fan is shown in Fig. 3, the vanes tapering from $\frac{5}{64}$ in. at the root to $\frac{3}{64}$ in. at the outer edge, the back-plate being $\frac{3}{32}$ in. thick and the centre hole cored ; a vacuum-cleaner nozzle is also shown. Aluminium pressure die-castings are extensively used in the manufacture of vacuum cleaners, the nozzle in Fig. 3 being an example, and also for all purposes where lightness and a clean, smooth finish are essential.

(*c*) Porosity constitutes a very serious limitation, the one factor to be taken into account when considering the adoption of pressure die-castings. Where finish, accuracy, and the elimination of machining costs are the main factors, porosity can be ignored, but where stresses are concerned, it requires careful consideration.

Porosity can be reduced to a minimum by careful design, venting and gating of the dies, but it does not follow that a perfectly homogeneous casting can be guaranteed, even when these points have been given every consideration, owing to the occlusion of gases, which cannot escape because of the speed at which the metal is forced into the dies, and also the rapid freezing of the metal.

(*d*) Pressure die-castings in any of the alloys at present in use are not at all suitable where high pressures are to be dealt with, owing to their crystaline structure and porous nature, particularly the zinc alloys. More suitable alloys for this class of work will be dealt with in a future article.

Fig. 3.—Vacuum Cleaner, Fan, and Nozzle.

One of the most serious limitations to the use of pressure die-castings is the comparatively small quantities called for. Die-casters are usually very reluctant to accept an order for less than from two to five thousand, according to the size and intricacies of the casting. These quantities often leave a very small margin of profit or no profit at all, even when the job has gone through without the many drawbacks met in starting up a new die. Repeat orders are the only means of recouping, and providing these are forthcoming the die-caster is generally satisfied ; unfortunately, however, a change of design frequently takes place, and the dies become obsolete.

GRAVITY PROCESS.

Die-castings are produced by this process in the same alloys as are used for the pressure process, and also in brass and aluminium bronze. In practice the gravity process has a wider range of utility than the pressure process. In view of this addition, it becomes necessary to divide

the metals used into two classes—viz., white metals and yellow metals,—the former comprising lead, tin, zinc, aluminium and their alloys, the latter brass and aluminium bronze only. Of the whole series, aluminium bronze has the least limitations. It has both chemical and physical properties, combined with its lower specific gravity, as compared with other yellow metals, which are not yet fully appreciated by engineers and manufacturers in this country, although many who do recognise its valuable properties are unable to take advantage of it for economical reasons, which constitute its most serious limitation.

The limitations of gravity die-casting are of the same character as those in pressure die-casting, and may be dealt with in the same order.

(*a*) The dies for the gravity process, owing to the more generous limits and necessary machining allowances, do not involve the same precision, care, and detail, either in design or construction, as the pressure dies. For the white metals a good cast-iron for the die and a good quality steel for the cores is all that is necessary to produce a satisfactory die-casting. The cost in this case does not constitute so great a limitation as in the case of the pressure die.

The cost of dies for aluminium bronze is much higher, as it is necessary, in order to procure the longest life possible, to cut the forms from an expensive heat-resisting steel, and then insert them in a cast-iron body or die sides, necessitating extra machining in the die sides for the reception of the steel forms, and also a considerably longer time for cutting the form in the special steel. This higher cost is too often the deciding factor against the use of aluminium bronze die-castings. Dies for brass can also be constructed on the same lines, but the steel-insert system is not so generally adopted.

(*b*) The tensile strength of the white metals is much higher in gravity die-castings than pressure die-castings, particularly the aluminium alloys. Bearing this fact in mind, gravity die-castings have a wider field of utility, where stresses are concerned, than pressure die-castings. It can be readily appreciated from the above that from the standpoint of tensile strength aluminium gravity die-castings are by far the superior of the two, and have practically no limitations, when sound, in their sphere of application. Aluminium gravity die-castings are used extensively in the motor-car industry, every component used being approximately two and a half to three times as light as compared with steel or brass, which means a great reduction in running costs. Crankcase covers, gear-boxes, brake-shoes, radiator parts, hub-caps, and many other components are made by this process. This is instancing only one of the many industries where there is a larger demand. A motor-car hydraulic jack body is shown in Fig. 4.

In regard to aluminium bronze and brass gravity die-castings, the matter of tensile strength assumes an entirely different character. The physical properties of brass are general knowledge. It may be mentioned, however, that the tensile is increased appreciably when die-cast. Aluminium bronze has the highest tensile strength of all the die-cast alloys, reaching as high as 44 tons per sq. inch when die-cast; this may be increased to some extent when subjected to heat-treatment. As far as aluminium bronze is concerned its tensile strength does not constitute a limitation.

(*c*) Porosity in gravity die-castings is not so pronounced in either the white or yellow metals. This is due to the greater facilities afforded in the design of the dies, to the method of gating and venting, and also to the slower rate of pouring, which allows sufficient time, in most instances, for the escape of the air and gases, which can be taken further care of by the operator in the control of pouring and the manipulation of the dies. Porosity in aluminium bronze die-castings is more easily eliminated by adequate venting than in the case of aluminium die-castings, and a strong homogeneous structure is usually obtained.

(*d*) In view of the greater tensile strength and the less liability to porosity in gravity die-castings, a sounder casting is the result, and resistance to pressure becomes almost a negligible quantity for reasonable pressures. Taking the whole group of white metals at present used, the aluminium alloys, particularly the copper aluminium alloys, are the only ones that can be recommended to meet the requirements where a white metal is essential.

Tin, lead, and zinc alloys still have their limitations in regard to resistance to pressure, and are not to be recommended for use under pressure conditions. Of the yellow metals, aluminium bronze die-castings are immensely superior from the pressure resistance standpoint, to any of the metals that can be die-cast. Owing to its great strength and fine structure, it may be used for pressures equal to that of any good mild steel, combined with its non-corrosive and high acid-resisting qualities, it stands pre-eminent amongst the non-ferrous group of metals, cost being its only limitation. Aluminium bronze gravity die-castings are used for parts where alternating stresses and shock are to be provided against, such as pump parts, worm-wheels for motor-cars, lorry differential gears, and selector forks used for gear-box speeds, as shown in Fig. 5. In some instances the only machining operation done is the reaming of the centre bore. The amount of machining eliminated as compared with a steel drop-forging is obvious, and although the material cost is higher, the ultimate saving can be appreciated.

Brush boxes for electric motors and dynamos are largely die-cast. Owing to the accuracy and finish, practically no machining is necessary, the box position for the brush being made to fine limits, and the casting can be used in most cases as it leaves the die. Its high melting point is a further advantage. Casement-window fittings are also

Fig. 1.—Zinc Base Alloy, Pressure Die-cast.

Fig. 5.—Aluminium Bronze Selector Fork.

Fig. 6.—Aluminium Bronze Assembled Handle and Plate.

Fig. 4. — Hydraulic Jack Body, Aluminium Alloy.

die-cast in large quantities, handles of plain and ornamental design, pin-stays to match, stay-boxes, spring catches, etc., are used as they leave the dies. An example of a die-cast aluminium bronze handle and plate assembled is illustrated in Fig. 6. This alloy can be highly polished, and, combined with its resistance to oxidation, casement-window fittings made in this metal can be used for the highest class of work, or, in the unpolished state, for chemical works. Aluminium bronze is not only die-cast in short lengths, but where it is necessary it can be obtained in the form of forged bars from $\frac{3}{16}$ in. upwards, in lengths of 6 ft. to 7 ft., with a maximum of 200 lb. per bar. Gear blanks can also be obtained up to 18 in. diameter. The forged bar is perfectly homogeneous, and its machining properties are equally good.

(*e*) The matter of quantities is not so great a drawback to the use of gravity die-castings as in the case of pressure die-castings; the cost of dies being lower, such small quantities as five hundred can be considered an economical proposition, and orders for this quantity are usually accepted by die-casters, in either the white or yellow metals. Under this heading the demand is limited by the cost of dies only, "dies nil" being absolutely out of the question unless the customer is prepared to have it included in the price of the castings.

It will be noted on perusal of this article that the limitations are far more pronounced in the case of pressure die-castings than gravity die-castings, but each has its own field of utility, and the demand is ever increasing. It will be further noted that no mention has been made of pressure die-casting in yellow metals. This will be dealt with in a further article. It may be said that the limitations of die-castings of to-day are not of such a serious nature as they were a few years ago. With due appreciation of the metallurgist and his laboratory, we may yet produce the much wished-for consistently homogeneous die-casting, which will remove all prejudice from the path of a growing and important industry.

In conclusion, it cannot be too strongly emphasised that there must be no limitations on the part of the responsible die-caster; he must know his business, otherwise all forethought and care on the part of others will be futile. It is not a question of following the line of least resistance, but of getting at the root of all the difficulties inherent to the die-casting processes, remembering that it is easier to make a bad casting than a good one.

Notes on Iron and Steel Foundry Practice

Part I.

By Ben Shaw.

Making sound castings is the primary object of the foundry. Many factors operate against their production.

IT may be profitable, at the commencement of a series of articles on foundry practice, to consider some of the factors that affect the production of sound castings. The direct application of scientific knowledge has undoubtedly had a considerable degree of influence on the work of the foundry, and no foundry, with any pretensions to quality of output, can hope for success without its aid. The degree of success attained in the production of the complex and difficult castings of to-day is largely due to the scientific investigation and elucidation of many factors that have retarded progress in the past through want of knowledge. It is a remarkable fact, however, that the problems of to-day become more, rather than less, difficult as our knowledge progresses, because it involves the consideration of increasingly complex problems. While scientific knowledge is essential, its application is not a guarantee that all castings will be sound, but the percentage of unsound work is likely to be considerably reduced.

THE PERSONAL ELEMENT.

It is the personal element which is of vital importance to the quality of product. Many other factors involved in casting production need very important consideration on a scientific basis to eliminate the risk of failure, but until the personal element in production is eliminated, founding will remain an art rather than a science. The result of the personal factor is a variable one, and depends largely upon the procedure adopted. Producing castings on a repetition basis, for instance, offers possibilities of reducing the human element according to the extent of dispensing with personal manipulation; a very large percentage of the work in the foundry, however, involves a high degree of personal skill and experience, and it is doubtful if it will ever be otherwise. It is the maintenance of that degree of skill, coupled with experience and knowledge, which has an important influence on the production of sound castings.

Of other factors which operate against the production of sound castings, that of contraction is not the least important. The expansion of metal on heating and the resulting contraction on cooling produce stresses in castings that may result in their fracture. These stresses are due to the operation of conflicting forces, and, even if fracture does not occur, the strength of the casting may be materially reduced; in fact, the casting may be unstable and unreliable unless the strains can be released. This difficulty is intensified by sudden changes in metal thickness, and is a factor of primary importance to the steel foundry and, to a less extent, the ironfounder. It is the irregular rate of cooling and the resistance offered by a mould during the time of cooling that creates the varying stresses. Rapid cooling intensifies the forces, whereas slow cooling, on the other hand, gives the metal an opportunity to accommodate itself better to the forces operating. It is frequently stated that the remedy lies in the adoption of sound principles of design, and while there is much truth in this view, it does not in itself constitute an infallible remedy. Limiting the design of castings to those in which no stress would be apparent would strike a very serious blow at the whole foundry industry. Modifications may be, and are, necessary to facilitate the production of sound castings, but the designer who has a comprehensive knowledge of the difficulties experienced in making, say, steel castings, can do much to assist the foundryman in overcoming difficulties and reducing stresses in castings.

CONTRACTION DIFFICULTIES.

In general, a gradual rather than a rapid change in sectional thickness is desirable, and the designer should endeavour to refrain from the use of sharp corners at abrupt changes in outline. The best results can only be obtained when the designer has a keen appreciation of the difficulties presented and understands the principles on which these can be modified. When these are ignored,

either through want of knowledge or on a question of expediency, there is bound to be loss in efficiency, which reacts on the production of sound castings. However much the designer of a casting may be able to facilitate and reduce the risk attached to its production, the moulder is largely responsible, and he must reduce the effect of contraction by intelligent anticipation and the use of various means at his disposal. These mainly consist of the use of chills to hasten the cooling of certain parts, various methods of reducing the strength of moulds at critical points, and the temporary inclusion of stiffeners or brackets in the casting which give strength and support to it at the time of cooling, and which are subsequently removed.

OTHER FACTORS.

Blowholes, shrinkage cavities, and porosity are other defects that render castings unsound. These are frequently of an embarrassing character, especially when much machining has been done to a casting before the unsoundness is discovered. The mixture of metal may be responsible for this condition of a casting, or it may be due to the low temperature at which it is cast, but the faulty condition of the mould and the sand used and inadequate facilities for exhausting gases generated usually result in these forms of unsoundness. Castings may be scabbed in such a way as to render them unsound. The raised scab, due to pressure of fluid metal on some weaker part of the mould, does not usually result in an unsound casting, but if a portion of the mould has been carried before the rush of metal, the scab formed is an indication that the broken part of the mould may be found embedded elsewhere in the casting. The hollow scab caused by pressure of gases against the metal gives the appearance of a buckle, and may reduce the strength sufficient to render the casting unsound.

Faulty placing of cores, either wrongly or with insufficient means of support to resist the rush and pressure of the metal, results in waster castings. These may not be unsound, but, since they do not conform to requirements, they are useless, excepting as scrap. The careless use of studs, chaplets, or nails may result in leakages when castings in which they are used are subjected to pressure. Rusty or dirty chaplets or the use of dull metal in moulds containing chaplets are also causes operating against the production of sound castings. Many other factors might be mentioned, but these suffice to show the influence of the personal element, and how necessary it is that a high degree of skill, together with knowledge and experience, should be maintained by the craftsmen involved, in order to reduce the percentage of wastage and loss resulting from unsoundness in castings.

COUNTERACTING DIFFICULTIES.

The difficulties referred to can be counteracted to a very considerable extent by a skilful moulder, but as a rule he has no control over the character and condition of the materials used in the preparation of his moulds, nor with the quality and fluidity of the metal subsequently cast. The right grade of moulding sand for the work to be done cannot be overestimated; its strength, refractoriness, and permeability, when formed into moulds, have an important bearing upon the quality of castings produced, and, for many classes of work, much experimental work is involved before the desired degree of success is attained. Many unsound or waster castings can be traced to the faulty condition or unsuitability of the moulding sand used. Even the facing wash applied to dry sand and loam moulds may be instrumental in causing faults to a casting that render it useless. Faults arising from the application of the wash are due to bad workmanship on the part of the moulder, but he does not, as a rule, prepare the composition of the wash, and consequently may not be responsible for defects arising from this cause. The quality and condition of the metal cast into a mould are usually outside the moulders' control, but the lack of soundness in a casting may be entirely due to bad melting practice. Thus, while the production of sound castings is largely dependent upon the moulder, it is only by the exercise of intelligent co-operation among those responsible for various operations that losses can be reduced to a minimum.

It is important, therefore, that a correct understanding of the difficulties presented in the production of sound castings should prevail, so that the methods and processes, together with machinery and melting plant, can be considered with a view to quality of product and economy of production. But, whatever the process, and however much the time utilised or care exercised, with the most modern equipment the soundness of the casting is the primary object.

(To be continued.)

NEW NON-FERROUS ALLOY.

A new alloy, known as P.M.G., has been devised, as the result of much research, which is claimed to be superior to gun metal. The research department of Messrs. Vickers-Armstrong's are responsible for the discovery, which this company have recently adopted as a substitute for gun metal. The alloy contains no tin, and, according to comparative tests carried out at Vickers' Sheffield laboratory, the alloy is not only cheaper but possesses physical advantages. The physical properties of the new alloy and those of Admiralty gun metal are given for comparison:—

	P.M.G.	Admiralty Quality Gunmetal.
Yield point	10—12 tons per sq. in. ..	7—9 tons per sq. in.
Ultimate tensile strength	18—22 " " ..	16 " "
Elongation on 2 in.	8—15% ..	8%
Izod impact test	20 ft.-lb. ..	14 ft.-lb.
Specific gravity ..	8·44 ..	8·82
Brinell hardness No.	90—110 ..	70—95

Tests on the metal when forged, rolled, drawn, and extruded gave the following results:—

Yield point: 20—22 tons per sq. in.
Ultimate tensile strength: 33 tons per sq. in.
Elongation on 2 in.: 38—42%.
Izod impact test: 36 ft.-lb.
Specific gravity: 8·44.
Brinell hardness No.: 135—150.

In a report to Messrs. Vickers-Armstrong with reference to this alloy, Professor Hanson, of Birmingham University, stated:—

"P.M.G. metal is a high-grade copper alloy possessing important qualities. It is an excellent casting alloy, cheaper to make than gun metal, and very much less liable to trouble through porosity and unsoundness. Moreover, the tests I have been able to make show P.M.G. metal to be distinctly superior to gun metal in strength and other mechanical properties. I believe the new alloy should find useful application in many directions in which gun metal, manganese, bronze, and other special brasses and bronzes are now used.

"Although my tests have all referred to material in which 10% of the hardener has been used to replace the same amount of tin in bronze, it seems probable that high-grade copper alloys possessing different mechanical properties could be obtained by alloying the hardener with copper in suitable proportions with or without zinc. P.M.G. metal can be readily forged, and in a worked condition possesses valuable properties as a high-tensile copper alloy possessing ample ductibility."

It is of interest to note the percentage of rejects when using this alloy for casting; our representative, on a recent visit to Barrow-in-Furness, was informed that out of over 3,000 castings only 18 have been rejected. It may reasonably be inferred that, in addition to lower cost of metal, there is a distinct economy on the production side, as, in the production of gun-metal castings, it is claimed to be reasonably good working practice on marine work when the rejects are as low as 5%. No special precautions are necessary in the foundry. The melting practice, preparation of moulds, and the casting conform to recognised practice for Admiralty gun-metal.

The metal is clean and fluid, runs into thin sections well, and takes a good impression. It is quiet in the fluid state, sets rapidly, and has apparently a short freezing range. It does not seem to oxidise readily at high temperatures, as castings removed from their moulds while red hot do not scale in the air. The sand is readily removed from the castings, and good surfaces are produced. The shrinkage is slightly in excess of gun-metal, and the use of heads to act as feeders is advisable.

Alloys in Steel Castings

Increased Severity of Working Conditions Widens Need for Alloy Steel Castings

By F. A. MELMOTH.

IT will be admitted equally by producers and users of steel castings that the demands made upon this branch of foundry product are increasing by leaps and bounds. It is no longer necessary to forgive all sorts and kinds of shortcomings on the score of the article being "only a casting." Production knowledge has so increased and amplified its grip of fundamental causes that such cases are now the exception and not the general rule. Progress, however, must be continuous, and in this short contribution the writer proposes to outline possibilities tending, in his opinion, both to progressive raising of the standard of capability of the steel casting and to a more general degree of satisfaction in its use. This latter must logically result in a widened application, and, therefore, be of value to the industry as a whole.

Methods of purchasing steel castings are at present of a type which demands so much weight for the smallest possible sum of money. Shortage in demand, and more organised purchasing, have resulted in the cultivation of a more exaggerated degree of competition than ever was the case formerly. Up to a certain point this is no doubt all to the good, but beyond the point at which a modern and reputable producer can see a return for effort, such methods defeat their own object. They may result either in attempts to cheapen the product by the elimination of a degree of *finesse* in its manufacture, often of more deep-seated importance than imagined, or may force out of production worthy exponents of the art whose pocket is too shallow to withstand prolonged production below cost. Almost all steel castings are purchased at so much per pound, per hundredweight, or per ton, and normally, the more weight per unit of cash expended the more likely is business to result.

PROPORTIONATE CASTING PROCESS.

The writer would suggest that a basis more equitable, and in the long run designed to hasten progress, would be to buy service and satisfaction at a higher rate per unit of weight, and he believes that progress in modern application of the steel casting will ultimately force this state of affairs on the purchaser. To particularise a few instances which give ground for this opinion, steam pressures, and consequently temperatures, are rising in the quest for higher and higher efficiencies. Speeds of all moving engineering productions are on the increase, it being now realised that time is too valuable a commodity to waste.

These two causes alone, when analysed, will be seen to justify the opinions already expressed. In the case of steam pressures and temperature increases, modern metallurgy is fully aware of their significance. It is awake to the fact that a given steel loses its resistance to stresses more or less in proportion to the rise in temperature. As both pressure and temperature are increasing, the strength losses from the temperature increase are accompanied by the imposition of greater stresses. Increased thickness, and therefore increased weight, represents a most unsatisfactory way out of the *impasse*, and certainly not a progressive one. The correct one, surely, is the development of steels of such type as will resist the degradation of intrinsic strength by increasing temperature to the greatest possible extent. The metallurgist is to a large extent ready to meet the requirement, but such qualities can only be built into a steel product by the expenditure of money, and the casting price must be proportionate.

In the case of the second of our points, that of increased speeds of motion, the argument is equally logical. Increased speeds usually mean the application of more power, and consequently larger involved stresses, in parts used in the structure. In all such cases, alternating stresses have to be contended with, and they will occur at increased speeds of alternation. Here, again, it does not seem logical to merely use the same material and increase its sectional area, as efficient transference of power into speed of motion is so closely bound up with weight. Progress lies only along the line of producing a casting of no more weight, but by its constitution capable of resisting the increased intensity of the working condition in which it is used.

TAKE ADVANTAGE OF PROGRESS.

Faster and more powerful locomotives, infinitely faster commercial road transport, are the order of the day. For every additional mile per hour, or in the case of steam pressure, for every additional pound per square inch, or degree of temperature, a portion of the available resistance to failure is absorbed. The common sense solution is surely that of taking full advantage of metallurgical progress. The writer would go so far as to suggest special specifications which would rigidly eliminate those producers who declined to see the finger of progress, and this, coupled with a fair price, would cause a greatly accelerated application of modern high-duty steels to steel castings production. There are many cases where working conditions have not altered materially, but where great savings in weight might be made by the use of a steel of higher capabilities. It has always seemed to the writer that weight over and above that necessary to give adequate performance is an extreme form of wastefulness.

The normal specification of what are known as mild-steel castings can be taken as covered by a specification range of 26 to 35 tons tensile per square inch, with elongation of 15 to 20%. These figures are to-day very easily met, and it would be safe to say that the test records of a progressive steel foundry would show average results 50% higher in ductility with no loss of tensile strength. This has largely come about by the practical application of increased knowledge of heat treatment, the significance of which is to-day much more fully appreciated. Indeed, it may be said that had not this been the case, the increased severity of working conditions would not even now have been met satisfactorily. Why not, therefore, go a step farther? An equal degree of ductility can be maintained, associated with much higher tensile strength, by the addition of one or more of the well-known metallic constituents of alloy steels, followed by suitable heat treatment. In many cases increased cost can be balanced by the economical effect of lighter weight, where sectional thickness permits of reduction without adding to difficulty of running the casting. Nickel, chromium, and molybdenum, separately or as varied combinations, offer a range of compositions of great value, now called upon only for very special purposes. Engineering progress will in the near future compel the use and development of such materials, and call for their application over a wider and ever-widening range of products.

The intention of this article is to bring to notice the fact that the necessary knowledge and material are available. All that is called for is a change of outlook, modification of designs to take full advantage of the capabilities of these steels in an economical manner, and a complete abandonment of the cheap-jack idea as applied to the purchase and sale of steel castings.

For resistance to corrosion in various media, the development of the demand has resulted in the production of a complete range of alloy steels meeting almost every possible condition. Such steels are available as castings, and the new sets of difficulties naturally encountered are being steadily overcome. The writer predicts that we are rapidly approaching the era of alloy steels for practically all purposes, and that only a far-sighted policy, on the part of both users and manufacturers of steel castings, can equip us adequately to meet the conditions which are sure to arise in the foundry as much as in any other branch of steel production.

PROGRESS NEEDED

It may be contended that already there are foundries commonly producing many types of alloy steels in casting form. This is perfectly true, but the basis of the steel production of the steel castings industry is almost identical to-day with what was the case fifteen or more years ago—namely, a comparatively soft straight-carbon material. It is only in very special cases that this is departed from, where it is definitely known that, despite thickness of section, a straight-carbon steel has no chance of meeting the service conditions. As instances, one could quote crushing rolls, cast armour, or parts subjected to gruelling wear in dredging machinery. In the first, the hardening influence of carbon content is usually intensified by the addition of chromium ; in the second, resistance to impact, plus great toughness, is obtained by the use of both nickel and chromium, with elaborate care in heat treatment, and in the latter, the alloy of iron and manganese discovered and developed by Sir Robert Hadfield, and known as manganese steel, is used to a very considerable extent. This latter material combines with a great toughness and ductility, when in a correctly heat-treated condition, the valuable property of work hardening on the parts subjected to heavy-wearing action. These, and many other combinations, are in fairly frequent use, but this use is dependent entirely on the incidence of a special purpose.

The suggestion now being put forward refers specifically to castings normally made in plain carbon steel, the necessary strength being obtained by thickness of section, using a practically standard material for their fabrication, and the contention is that a new point of view is due to become operative. In many cases this will be by sheer force of new demand by engineering progress, and it is the writer's opinion that in a multitude of other cases the designer could usefully adopt the newer point of view, by designing to the capabilities of higher duty steels, rather than to those constituting the ordinary run of steel foundry production.

COMPARATIVE QUALITIES.

As instances of the capabilities of such steels, the following can be quoted, the carbon steel being given for comparison :—

—	Yield Point Tons per Sq. In.	Maximum Stress. Tons per Sq. In.	Elongation % on 2 In.	Reduction of Area.
Plain carbon steel annealed	17.2	30.8	35.0	57.2
Carbon steel with 0.3 molybdenum normalised and tempered	24.8	36.8	28.0	44.8
Carbon steel with 1% nickel, annealed only	25.6	41.6	24.0	33.6
2% chromium, 1% nickel, normalised and tempered	27.6	40.8	28.0	64.0
3% nickel, 1% chromium, quenched and tempered	38.0 ap.	54.0	21.0	50.0
Nickel-chrome molybdenum, quenched and tempered..	53.2	58.8	21.0	47.2

The above are all from actual castings, and show plainly the increased strength, accompanied by ductility in excess of that indicated by the usual elongation percentage demanded in standard steel castings specifications. The most noticeable feature is the greatly increased yield point, of very vital importance to the designer, as it is only inside this figure that any manufactured steel article can be safely stressed.

Time and time again in technical discussions the foundry has been stigmatised as the " Cinderella " of the engineering trades. There is no logical reason why this should be. The skill and craftsmanship demanded, and the organisation complication, are of such high standard that our foundries should occupy a very high place in the industrial and technical world. The utilisation to the fullest extent of the latest metallurgical knowledge, with a consequent elevation of the standard of the product, could only be attended by an immediate improvement in this direction, and, in addition, result in an enhanced reputation for service, which should be, and usually is, the very foundation of all business.

ELECTRIC HEAT-TREATMENT OF METALS

(*Continued from page 58*)

electric furnace the depth of case is much more readily controlled, and what is more important is that the depth is uniform, and the difficulties due to flaking are overcome.

In the nitration process, whereby certain alloy steels containing chiefly aluminium and chromium are case-hardened by heating in an atmosphere of ammonia, the temperature is limited to a very narrow range—namely, plus or minus 5° C. at 500. If this is exceeded, certain nitrogen compounds are formed which are deleterious to the quality of the case, and the only furnace to meet these strict requirements has been an electrically-heated one.

Nothing could be more fallacious than a direct comparison of the price of electric and gaseous therms. It must be remembered that the cost of heating is only a single item in the balance-sheet. Many an electrically-heated process which appears uneconomical on the surface will be found profitable in the long run, when all factors are taken into consideration, such as improved quality of product and hence greater market value, the minimising of spoilage, reduction in labour in handling of waste products, better working conditions, less fire hazard and less insurance, less floor space, and lower cost of maintenance.

There has been, and not without cause, a certain trepidation on the part of manufacturers before embarking on a new system of heating, involving considerable capital outlay, but the school of experience has taught that the objection no longer holds good, and in the majority of cases, especially in the examples cited, the change is fully justified by the improved results.

THE DEVELOPMENT OF MATERIALS FOR AIRCRAFT PURPOSES.

In the course of a lecture delivered before the Royal Aeronautical Society, Dr. Rosenhain surveyed the whole field of materials used in aircraft construction from the point of view of the properties required, so that an estimate could be formed of the present direction and future tendencies of the general trend of development. The rates of strength to weight, stiffness, resistance to fatigue, resistance to wear, to corrosion and high temperatures, and facility of fabrication by jointing and forming, were considered. An account was given of some alloys of exceptionally high strength at high temperature recently studied at the N.P.L., and reference was made to the possibility of further improving such materials. The ultra-light alloys of magnesium were discussed, as well as beryllium and its alloys, and certain standard light alloys and steels. Part of the paper contained a discussion on welding of materials, particularly alloys.

MACHINING STAINLESS STEEL

BY J. H. BARBER,

Machine Shop Manager, Thos. Firth and Sons, Ltd.

A FEW years ago, when stainless steels were first put on the market, their application was largely confined to the manufacture of cutlery. It was not long, however, before it was recognised that a much more extensive field existed for the application of non-corrosive steels for industrial purposes.

The names of Thos. Firth and Sons, Ltd., Sheffield, has been identified with these non-corrosive materials from their inception, and the purpose of this article is to deal with the machining of this firm's "Staybrite" steel.

It will not be out of place to state briefly the characteristic properties of this steel. It is a high-percentage chromium steel to which a substantial addition of nickel has been made. The composition is kept within well-defined limits, and a high degree of uniformity in its properties may thus be relied upon. Its characteristics may briefly be explained by saying that in its fully softened condition it has a yield point similar to that of mild steel, but has twice its ductility, and a high maximum breaking stress. It differs, however, from ordinary carbon steels in that it is not affected by many of the industrial acids, etc., which lead to the rapid corrosion of ordinary steels. In this softened condition it can readily be pressed, in the cold state, into complicated forms. It is produced in bars, sheets, etc., and it is particularly with the machining that this article is concerned.

In the initial stages of its use some difficulty was experienced in turning, drilling, milling, etc., but, after a little experience, and with slightly modified conditions, these various operations were carried out without undue difficulty. Machines must be rigid, the slides in good condition, the tool well supported with the minimum of overhang, and chatter eliminated. The essentials for satisfactorily machining may be defined under four headings :—

(1) Rigidity of the job.
(2) Rigidity of the machine tool.
(3) Rigidity of the cutting tool.
(4) The use of a suitable cutting tool, which must be a good high-speed steel.

The reason for emphasizing these conditions is that if the tool, for any of the reasons mentioned, is allowed to run without cutting, the work-hardening of the steel thus caused may give trouble.

Turning.—With regard to tool angles, rather more front and side rake should be allowed than is the practice with tools for use on ordinary steel, from 10° to 20° being usual when sliding and surfacing. The average cutting speeds are covered in the range, 55 ft. to 60 ft. per min. for light-roughing cuts ; 80 ft. to 100 ft. per min. for light-finishing cuts will leave an excellent finish. Tools should be given a front clearance angle of about 10°. Feeds of 60 to 80 per lineal inch will be found suitable.

The life of a turning tool is naturally governed by the class of steel used, and for this reason one of the newer cobalt high-speed steels is recommended.

Drilling.—In the same way for drilling, it is economical to use the best drill procurable, and the makers of "Staybrite" supply twist-drills made from cobalt tungsten high-speed steel which are particularly adapted for use on these tough alloy steels.

To secure rigidity, it is desirable that the drill should be as short as possible, and in the case of small diameters it is advisable to grip the drill as low down as possible, with the object of reducing spring. The cutting lips should be ground with rather more back clearance, as indicated by the illustration in Fig. 1, than is recognised as standard for use on ordinary steel ; the point of the drill should be thinned in the customary way, and all spindle play eliminated. With these conditions observed, most of the difficulties of drilling will disappear. A lubricant should be used when drilling and milling.

Fig. 1.

The following table shows representative speeds for high-speed steel twist-drills :—

Diameter of Drill. In.		Revolutions per Minute.		Feed per Revolution In.
1/16	..	1500	..	0·001
1/8	..	800	..	0·0025
1/4	..	400	..	0·005
1/2	..	225	..	0·0075
3/4	..	180	..	0·10
1	..	150	..	0·011

The chart Fig. 2 indicates in detail the speeds and feeds recommended.

For drilling, the job should be only very lightly centre-punched, the drill fed straight into the work, and not allowed to dwell, as is frequently done on ordinary material. It should, as stated, be fed straight into the work, so that it is cutting continuously.

Milling.—This presents no difficulty, but, again, it is strongly advised that everything about the machine and cutter should be rigid, and that a cutter having from 10° to 15° of undercut should be used, and, of course, kept sharp. Milling speeds will be between 50 ft. and 60 ft. per min. for average conditions, and 70 ft. per min. for light cuts.

Sawing.—In the initial stages there existed a substantial difficulty in sawing stainless steel, but, fortunately, parallel with the development of this steel a high-speed steel hacksaw blade was evolved which satisfactorily solved the problem. Using high-speed steel hacksaw blades, no difficulty is experienced in sawing up stainless steel bars, etc.

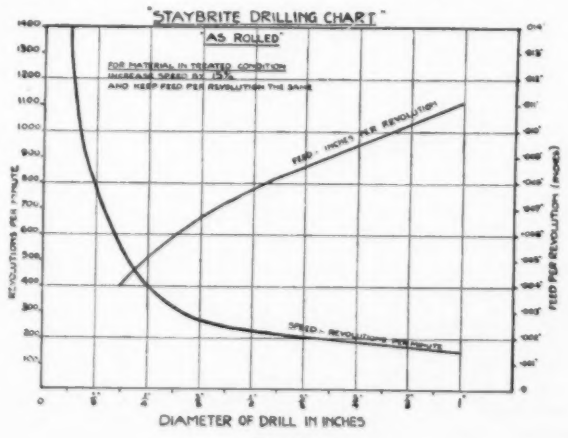

"STAYBRITE DRILLING CHART"
"AS ROLLED"
FOR MATERIAL IN TREATED CONDITION INCREASE SPEED BY 15% AND KEEP FEED PER REVOLUTION THE SAME
FEED - INCHES PER REVOLUTION
SPEED - REVOLUTIONS PER MINUTE
REVOLUTIONS PER MINUTE
FEED PER REVOLUTION (INCHES)
DIAMETER OF DRILL IN INCHES

Fig. 2.

(*Continued on page* 77.)

DETERMINING MACHINABILITY FACTORS

Power required to Drill Cast Iron and Steel.

THE machinability of metals involves so many factors, due to the wide variety of types of metals and the treatment to which they are subjected, that data on the subject is difficult to obtain. A series of drilling tests on materials shown in table have been carried out by Professor O. W. Boston, of Michigan University, and C. J. Oxford, in an effort to determine these factors, and also to obtain data on the torque, thrust, and net horse-power developed at the point of drills when using some of the modern high-speed steel twist-drills, on a variety of types of steels and cast irons used in modern industry. The results of these tests, contributed by the Special Research Committee on Cutting of Metals, was presented on the third of this month at the annual meeting of the American Society of Mechanical Engineers.

In the tests, drills ranging in diameter from ½ in. to 1½ in. of the standard twist-drill type were used. The drills were considered sharp in all tests. A coolant consisting of one part of soluble oil and 16 parts of water was used in all tests. The materials cut consisted of one regular machining cast iron and one cast iron made up of 20% charcoal pig iron, together with 17 steels of a wide variety of chemical analyses, which were selected to cover the steels commonly used in modern manufacture. Data as to drilling torque, thrust, computed horse-power at the drill point, and net horse-power supplied to the machine as measured on a recording wattmeter, are given under two headings: commercial tests and special tests. All commercial tests were run at a peripheral speed of the drill of approximately 60 ft. per min. The feed for each drill size was as near to those given in the usual commercial drilling table as the change-gears available would permit. They were as follows:—0·009 in. per rev. feed for the ½ in. diameter drill, 0·011 in. for the ⅝ in. drill, 0·012 in. for the ¾ in. drill, 0·013 in. for the 1 in. drill, and 0·015 in. for the 1¼ in. and 1½ in. diameter drills.

MATERIALS USED, SHOWING THE S.A.E. SPECIFICATIONS, THE CHEMICAL ANALYSIS, THE HEAT-TREATMENT, AND THE BRINELL, ROCKWELL, AND SCLEROSCOPE NUMBERS.

Bar No.	S.A.E. Specifications.	Chemical Analysis.	Heat-treatment, Deg.	Hardness.			
				Brinell Dia.	Brinell No.	Rockwell "B" Scale.	Sclero-scope No.
1	1,020	Commercial	None	5·1	137	84	29
2	1,045	Commercial	Normalise 1,600 Anneal 1,475	4·75	159	82	28
3	2,320	Commercial	Anneal 1,600	4·7	163	85·5	25
4	3,120	Commercial	Anneal 1,600	5·0	143	75	24
5	3,135	Commercial	Normalise 1,575 Anneal 1,500	4·35	192	88·5	29
6	6,150	C. 0·50 Mang. 0·20 Chr. 0·80 Van. 0·20	Normalise 1,650 Anneal 1,550	4·4	187	86·5	29
7	3,250	C. 0·50 Chr. 1·09 Ni. 1·75	Normalise 1,650 Anneal 1,475	4·2	207	92·5	30
8	3,140	C. 0·50 Chr. 0·60 Ni. 1·25	Normalise 1,650 Anneal 1,500	4·3	196	92	30
9	2,330	Commercial	Anneal 1,500 Reanneal 1,400	4·25	202	93·3	32
10	2,340	Commercial	Anneal 1,500 Reanneal 1,400	4·2	207	93·5	32
11	6,120	Commercial	Anneal 1,500 Reanneal 1,400	5·1	137	76·5	25
12	6,130	Commercial	Anneal 1,500 Reanneal 1,400	4·8	156	81·5	28
13	6,140	Commercial	Anneal 1,500 Reanneal 1,400	4·7	163	85·5	28
14	9,250	Commercial	Anneal 1,500 Reanneal 1,400	4·25	202	93	32
15	Chr. Molyb.	C. 0·33 Si 0·20 Mang. 0·50 Ph. 0·011 Su. 0·010 Chr. 0·66 Molyb. 0·18	Anneal 1,500 Reanneal 1,400	4·8	156	77·5	27
16	Chr. Molyb.	C. 0·28 Si. 0·23 Mang. 0·52 Ph. 0·028 Su. 0·017 Chr. 0·65 Molyb. 0·19	Anneal 1,500 Reanneal 1,400	4·8	156	79	27
19	1,095	Tool steel	Anneal	—	154	85	25
18	C. I.	Charcoal	As cast	4·7	163	83	32
20	C. I.	Regular	As cast	—	143	76	30

Special tests were run on various cast irons and steels, so that the influence of the speed, feed, and drill diameter could be determined, in order that the results of the commercial drilling tests could be extended to cover any other conditions of drilling for each material. It was found from these special tests that the thrust for both cast iron and steel increased in direct proportion to the drill diameter d; that the torque increased in proportion to d^2 for cast iron and $d^{1.8}$ for steel. The thrust increased with an increase in feed f, but at a rate as slow as $f^{0.6}$ for both cast iron and steel. The torque increased as $f^{0.6}$ for cast iron, but $f^{0.78}$ for steel. It was found that the torque and thrust remained practically constant over the whole range of speeds covered from 74 to 441 r.p.m. for each drill size and feed.

An attempt was made to correlate the hardness values of the materials determined by the Brinell, Rockwell, scleroscope, and Herbert pendulum hardness testers, with the results obtained from the drilling tests.

It was concluded that no satisfactory relation exists between these properties, and that machinability constants for any material would have to be determined from actual drilling tests. From the data available, it appears that the type of steel, the carbon content, and the microstructure are all very important factors in the determination of this machinability factor.

In arriving at the conclusions given, it is to be understood that the drills used were supposed at all times to have a keen cutting edge and point—that is, they were in a sharp condition. A cutting fluid consisting of one part of soluble oil mixed with sixteen parts of water was used on all tests. Actual experimental results are given in every instance, rather than values determined by smoothing out curves. For this reason there are some slight inconsistencies in the data presented.

1. The torque remains practically constant at speeds ranging from 74 to 441 r.p.m. for both cast iron and steel, and for various drill diameters when operating under constant conditions of feed, lubrication, and material.

2. The thrust remains practically constant at speeds ranging from 74 to 441 r.p.m. for both cast iron and steel, and for various drill diameters when operating under constant conditions of feed, lubrication, and material.

3. The net input which equals the gross minus the load on the machine running idly, increases directly with the speed for the conditions mentioned under 1 and 2.

4. The torque increases with the feed, but at a slower rate for a constant drill diameter and speed. For two cast irons, one carbon and one alloy steel for various drill diameters from $\frac{1}{2}$ in. to $1\frac{1}{2}$ in., and for different speeds, the average conditions are represented by the following :—

T = a function of $f^{0.6}$, for cast iron, and

T = a function of $f^{0.78}$, for steel.

5. The thrust increases with the feed, but at a slower rate when drilling cast iron and steel. For the conditions mentioned in 4, the following formulæ represent average values :—

$T\,h$ = a function of $f^{0.6}$, for cast iron.

$T\,h$ = a function of $f^{0.6}$, for a carbon and an alloy steel.

6. In drilling a straight carbon and an alloy steel with drills varying from $\frac{1}{2}$ in. to $1\frac{1}{2}$ in. in diameter, at constant speeds of 153 and 230 r.p.m., the torque increases with the drill diameter, but at a greater rate for both cast iron and steel. Average conditions for two cast irons, a plain carbon, and an alloy steel are represented as follows :—

T = a function of d^2, for cast iron.

T = a function of $d^{1.8}$, for steel.

This may be expressed again as follows :—

$\frac{T_1}{T_2} = \frac{d_1^{\,n}}{d_2^{\,n}}$, in which T_1 and d_1 are the known torque and drill diameter and T_2 is the desired torque for the new diameter d_2. n is 2·0 for cast iron and 1·8 for steel.

7. For the conditions outlined under 6 the thrust is found to vary almost exactly in direct proportion to the diameter of the drill. The values for thrust may be expressed, then, as follows :—

$T\,h$ = a function of d, for cast iron, and

$T\,h$ = a function of d, for steel.

8. Combining the above relations of torque and thrust for cast iron and steel, general equations may be written as follows :—

$T = C_1 f^{0.6} d^2$, for cast iron.

$T\,h = C_3 f^{0.6} d$, for cast iron.

$T = C_2 f^{0.78} d^{1.8}$, for steel, and

$T\,h = C_4 f^{0.6} d$, for steel, in which T is the torque in foot-pounds, $T\,h$ is the thrust in pounds, d is the diameter of the drill in inches, f is the feed of the drill in inches per revolution, and C may be called a " hardness class " number or " machinability factor "—that is, a constant depending upon the material being drilled. At the present time the authors know of no way, except by actual drilling tests, to predetermine these constants for torque and thrust for a particular metal.

The output horse-power at the drill point may be computed from the torque T and thrust $T\,h$, from the formula—

$$\text{Horse-power (computed output)} = \frac{2\pi T N}{33{,}000} + \frac{T\,h\,f\,N}{12 \times 33{,}000}$$

$$= 0{\cdot}0001904\,T N + 0{\cdot}00000252\,T\,h\,f\,N = N\,(C_5 T + C_6\,T\,h\,f),$$

in which N is the revolution per minute of the drill, f is the feed in inches per revolution of the drill, and C_5 and C_6 are constants. It is seen then that the output horse-power at the drill point as computed from the torque and thrust is directly proportional to N. While the value of the thrust in pounds is usually relatively large, the resultant horse-power is only $\frac{1}{2}$ to 2% of the total computed. For general purposes, then, the output horse-power developed at the point of the drill may be assumed to be due only to the torque or—

Horse-power (computed output) = 0·0001904 T N, in which—

$T = C_1 f^{0.6} d^2$, for cast iron, or

$T = C_2 f^{0.78} d^{1.8}$ for steel.

The results of the metallographic study may be summed up as follows :—The 17 samples of steel as a group are arbitrarily divided into three classes, the first class showing a normal pearlitic structure, or one showing a very slight spheroidisation ; the second class consisting of those steels which are partly spheroidised—that is, advanced beyond the beginning stage of spheroidisation ; and the third class, those very nearly completely spheroidised. A direct connection with the torque in drilling is evident, although the greater the torque the greater is the degree of spheroidisation. This is just the opposite of what might be expected if all bars were of the same chemical composition.

By grouping the materials according to chemical composition in order of increasing torque on a 1-in. drill, a fairly close grouping, according to chemical composition or type of steel, is obtained. This arrangement tends to indicate that the type of steel, the carbon content, and the microstructure are all important factors in determining the value of the torque in drilling.

No satisfactory correlation between the hardness values as determined by the Brinell, Rockwell, scleroscope, or the Herbert pendulum hardness tester, and the drilling torque for a given specimen, is evident.

MACHINING STAINLESS STEEL.

(*Continued from page* 75)

An engineer contemplating the employment of this material will undoubtedly run into difficulty if he tries to cut it with a carbon or ordinary alloy steel blade. Normally, the high-speed hacksaw blades may be run at 90–100 strokes a minute, and here again the blade should be kept cutting continuously and not allowed to rub.

Filing.—This does not present much difficulty, but in this direction also special files have been evolved which, whilst showing an economy on practically all materials, is a very definite gain when filing a tough material such as stainless steel.

Tapping.—Tapping holes for stainless steels should be rather larger than usually employed for ordinary steel, as the material swells up under the influence of the tapping. The following is a short list of suggested tapping sizes :—

For			In.
No. 5 B.A.	Use	No. 36 drill ..	0·1065
No. 1 B.A.	,,	4·5 mm. ,, ..	0·1770
$\frac{1}{4}$ in. Whit.	,,	$\frac{13}{64}$ in. ,, ..	0·2031
$\frac{5}{16}$ in. Whit.	,,	$\frac{5}{16}$ in. ,, ..	0·3125
$\frac{3}{8}$ in. Whit.	,,	10·5 mm. ,, ..	0·4134
$\frac{1}{2}$ in. Whit.	,,	$\frac{13}{64}$ in. ,, ..	0·6406
1 in. Whit.	,,	$\frac{55}{64}$ in. ,, ..	0·8594

Nothing but the best taps should be used for this purpose, ground thread taps being perhaps most suitable ; a first-class four-fluted tap will work satisfactorily if kept sharp, preferably with a little undercut to the threads.

PRESIDENT OF THE BRITISH ENGINEERS' ASSOCIATION.

SIR GILBERT C. VYLE has been re-elected President of the British Engineers' Association for the year 1929-1930.

EFFICIENCY OF WELDED JOINTS.

DURING recent years there has been an increasing tendency to employ fusion welding in production of pressure vessels, and the absence of any rules or regulations to guide design is unsatisfactory to all concerned. The much-used argument that because the strength of a weld is an uncertain factor no attempt can be made to deal with welded joints on a scientific basis has been felt to be unsatisfactory. In general, welded joints have been established as an engineering production, and it is quite clear that there should be some rational basis for rating their strength relatively to one another. With good metal of a given quality each form of weld has a definite calculable strength, similar to any other structure, and it obviously should be rated proportionately to this strength. In this respect, for instance, the British Engine and Electrical Insurance Co., Ltd., have felt that what was desired was that welded joints should be treated in some such manner as riveted joints, and dealt with on an efficiency basis, and have made an inquiry, limited to the construction of non-fired vessels, on the following considerations.

"JOINT EFFICIENCY."

A statement that a joint of a particular form has a given strength is of little value, for a butt weld made by one process may have a strength of 20 tons per sq. in., but when made with another welding rod, or by a different process or operator, 40 tons per sq. in. Another factor to be considered is that the strength of a weld made with electrodes of the same type will vary with the strength of the plate on which the weld is made. The absolute strength of a joint of a particular form has been considered of no consequence. The most convenient information is considered to be the strength expressed as a percentage—described as the "joint efficiency"—of a single-V butt weld, made on similar material with the same welding rod by the same operator, the surfaces of the butt weld being machined down to the level of the plate. As the strength of a reasonably well-made butt weld, made with a given welding rod under standard conditions, is generally a known quantity, knowledge of the joint efficiency gives at once the absolute strength of a particular form of joint made with any welding rod. For the work undertaken it has been found necessary to design several forms of test-piece. With a joint of higher tensile strength than the plate there is difficulty in determining accurately the strength of the weld. Several methods of overcoming the difficulty suggest themselves, none being free from some objection.

The various components of a joint may be tested individually, and the efficiency deduced by summation. This is liable to lead to considerable inaccuracy owing to the stress in the assembled joint being unequally distributed, and the actual combined strength being less than the sum of the components. A higher tonnage plate may be used with the object of ensuring that failure takes place at welds. That introduces a false set of conditions at the junction of a weld with the parent metal, owing to carbon diffusing from the plate into the weld metal, making it unduly strong there. In addition, the strength of the weld to resist a steady tensile load may thereby be raised above its normal value, in a way somewhat similar to that occurring in a test specimen of uniform composition, when it is nicked.

Fillet welds may be made on only a portion of the edge of cover straps. This is an excellent means of overcoming the difficulty with some forms of test strip. It, however, necessitates careful preparation of the edges of the straps before the welding is carried out, which is not always convenient, and it cannot be applied to every form of test strip. With flexible joints this method is inaccurate, for the joint is stiffened by an amount greater than it would be with the actual joint represented. The test-piece may be machined down in some particular manner, when welded. With many designs extant too high a result is obtained, owing to the specimen being rendered stiffer than the actual joint, and to the load being transferred to the components in an incorrect proportion. With joints stronger than the plate this method was adopted for the tests wherever possible, but with specially designed test-pieces, though the forms of test-piece adopted may not be perfection, an effort was made to ensure that they should represent the actual strength as accurately as possible. In every case the design was such that the surfaces of contact of fillet welds, carrying a tensile load, bore their full share of the load, a desideratum that is by no means always reached with other designs of test-piece.

VARIOUS JOINTS.

Although it is possible to produce a butt joint the strength of which, when reinforced, is equal to, or even slightly greater than, that of the plate itself, there are so many uncertain elements in a welded joint that under no circumstances can a butt-welded joint be credited with more than half the plate strength. That handicaps the welder in making use of what otherwise might be a far cheaper process than riveting, and one with a special advantage where a tight seam is an important consideration. As the strength allowed for any other form of joint must be reduced in a similar manner, it is to be inferred that, though the welding of joints has not the inherent disadvantage of weakening the plate that the drilling of holes for rivets has, the full strength of the plate can only be utilised if the design of joints is improved.

A lap joint with a single fillet has, where there is no bending stress, a strength of only about 60% that of a butt-welded plate, and obviously does not fulfil the rôle. Though suited to a circumferential seam, it is absolutely impermissible for a longitudinal seam, owing to bending stresses. Under ideal conditions considerable increase of strength can be attained by a fillet being formed at both edges of the lap, but in practice it is difficult to ensure that both fillets will take their full share of the load, and still more difficult to ensure that a maker will lay the plates with the necessary accurate fit. Even where there are no bending stresses the joint has a strength of only about 20% more than that of a butt-welded plate, and, owing to the introduction of such stresses, it is unsuitable for a longitudinal seam, while it is permissible only when the plate is very thin, and then only at a greatly reduced rating.

As it is always preferable for a dished end to be held independently of the joint—for instance, by the end of the shell being turned in over the flange—and as, with a circumferential seam joining two shell-plates together, it is preferable for straps to be fitted, superior constructions would be discouraged if circumferential seams were rated on the result of test figures. Therefore, though a higher stress is allowed for a circumferential lap-joint with a double fillet than for a butt joint, both joints are rated below half the test strength.

On paper a joggled lap-joint with two welds is a distinct improvement, as it is capable of giving appreciably better results than a double-fillet lap weld when subjected to a static tensile test. It, however, requires to be made with great accuracy, and without the plate being thinned while being set. Even then it is subjected to a bending stress, and there is a doubt whether the fillet weld is taking its fair share of the load. When subjected to the stresses of service its behaviour will always be a matter of uncertainty, and therefore it is only suitable within limits for a longitudinal seam. No definite rating is named, on account of the joint not having been applied to pressure vessels. If welded seams of a boiler are to have the same margin of safety as riveted seams, a radical departure from present designs and practices will be necessary.

Common Errors in Steel-Making

BY Walter Lister.

Part I.

Charging and Melting.

AT the present time there are still a large number of Siemens acid furnaces in operation, and the majority of them are hand charged. This is more from preference than necessity, as the pig iron can be more evenly distributed over the bottom by hand, with consequently less corrosion by the oxidised scrap. But a common error is to put all the pig-iron on the bottom and all the scrap on top. This is a mistake, because the scrap takes a much longer time to melt by this method of charging, and is thus exposed to a sulphur-laden gas much longer than necessary; and sulphur absorbed by an acid charge cannot be eliminated, and must perforce appear in the finished steel.

ACID COLD CHARGE.

It is more important to consider the quality of the ultimate product than to have too much tender regard for the furnace hearth. At the same time, both points should have due consideration. It is quite sufficient to cover the bottom with one layer of pig-iron and save the remainder to charge on top of the scrap. The pig-iron on top will melt quickly, and, running among the scrap, help it also to melt more quickly. Moreover, the pig iron melting and coming into contact with the oxidised scrap, immediately forms a slag, which protects the charge from undue absorption of sulphur. The following equations will illustrate the formation of the slag :—

Si	+	O_2	=	SiO_2
(silicon of the pig)		(oxygen of the air)		(silica)
SiO_2	+	FeO	=	$FeO.SiO_2$
(silica from the pig)		(rust on the scrap)		(slag)

Another error is to smother the furnace too much when melting. Some melters almost cut off the chimney draught entirely, with the idea of keeping all the gas in the furnace, and so, as they think, quicken up the melt. This is entirely wrong, and usually has the contrary effect. The furnace is full of products of combustion instead of live gas. Furnaces have the draught impeded quickly enough by accumulations of dust and slag in the regenerating chambers, without deliberately cutting-off the draught with the chimney damper. By this I don't mean that the chimney damper should always be open to its fullest extent. A new furnace will require less chimney than an old one, and less chimney draught will be required in melting than in working down, but there is a limit to which the draught should be impeded by the chimney damper during melting. It should not be impeded to such an extent than gas blows out at the doors. This happens soon enough in the ordinary course of events, and is a sign that the furnace has only a short time to live, owing to lung trouble, and it should never happen to a young and vigorous furnace. Moreover, it causes an excessive back pressure on the gas producers retarding the gasification of the coal.

Another evil arising is the greater damage done to door arches and jambs. Gas blows out between the arch and the top of the door like a blow-pipe flame, with the result that the bill for week-end repairs mounts up considerably.

Ideal melting conditions should consist of a full body of gas in the furnace, the end of the flame wavy and luminous and just licking the ports, and just the slightest show of flame occasionally appearing at the top of the door nearest the out-going end. There should never be any flame coming out of the middle door. The air screw should be slightly lowered, so that there is no excess of air, but just sufficient to ensure complete combustion of the gas.

In basic working, of course, the hearth is always covered with scrap instead of pig iron. This is in order to protect the basic bottom from the acid silica formed by the oxidation of the pig. But even this is sometimes carried too far.

BASIC COLD CHARGE.

Many melters endeavour to get the scrap in before commencing to charge the pig iron. This is quite good practice if the furnace can be completely charged in one operation, but with basic scrap this is more the exception than the rule. As is well known, commercial basic scrap is, contrary to acid scrap, of all shapes, sizes and weights, and, with regard to the latter, more often feather-weight than heavy-weight. With this sort of scrap the furnace is full before any pig can be charged, and very often before all the scrap is charged. Now the melter who believes in getting all his scrap in first has to wait until the first portion melts before he can charge the remainder. And what happens? A pasty mass of soft, lifeless iron forms on the bed of the furnace, and more cold stuff is charged on top. The pasty mass becomes a nasty mess, because the portion first semi-melted is further chilled and remains for a long time in this condition, even after the pig and the last portion of the scrap are all melted. If enough pig iron has been charged, this bottom layer of scrap will eventually all boil up, after which working down can proceed, but at least an hour will have been lost during this time. If nothing worse than this happens the melter can be thankful, but very often he does not get off so lightly. Before the charge is all melted up it may go soft. If a high carbon steel is required it is hopeless to try to make it. There will be trouble in eliminating phosphorus and sulphur. The best that can be done is to pig it back and when sufficiently hot, and phosphorus and sulphur within limits, tap the charge for some low-carbon steel. Anything from two to three hours (and sometimes much more) may be lost in this process, to say nothing of the danger of a break-out due to the overloading of the furnace.

WHEN SECOND CHARGE IS NECESSARY.

Where it is not possible to complete the charge in one operation, half the pig iron should always be charged with the first portion of scrap. For instance, in a 50-ton furnace 20 tons of scrap and 10 tons of pig may be charged for the first round. This will melt down quickly into a lively pool of high-carbon semi-steel, which will remain liquid at a low temperature and will not set back on the addition of further cold material. Lime can be added into the liquid first portion before completing the charge, which will consist of, say, a further 15 tons of scrap and 5 to 8 tons more of pig. The quantity of pig used should vary according to the state of oxidation of the scrap, but the author believes there are many shops where this sort of thing is never taken into account. The same quantity is habitually used, irrespective of the condition of the scrap, with the result that if things are just right it is more in the nature of an accident than design. No melting-shop should have to depend on " accidents " of this sort.

To go back a little, it is very important that lime should be added before completing the second round, as this forms a slag which combines with the phosphorus of the bath during the further melting, so that by the time the whole charge is clear, much of the phosphorus, and probably some of the sulphur, has been eliminated. The charge

will be less oxidised, and will melt at a higher temperature, coming on to a good boil more quickly, the conditions thus being more favourable to the elimination of sulphur.

100% *Hot-metal Charge.*—Hot-metal charging, with the exception of the Talbot process, is much more severe on the furnace bottom than cold charging. This is due to the corrosive effect of the large amount of iron ore necessarily charged to eliminate the larger amount of metalloids which the blast-furnace iron contains. But often the furnace bottom suffers more than it need do by faulty charging. A common error is to allow the lime and ore to become semi-melted before pouring in the ladle of molten iron. This is done with the idea of getting a stronger reaction from the hot oxides. It certainly does have this effect, and probably on one or two charges a little time may be gained in working down, but this is always more than wiped out by delays due to necessary repairs to the hearth. If the oxides are allowed to become semi-melted they eat into and rot the furnace hearth, causing continuous trouble and delay. Moreover, some of the lime will stick to the bottom, which very soon assumes an appearance of hills and dales, or perhaps, more correctly speaking, mountains and lakes, the lakes being pools of steel left in holes. The hot metal should be poured in as soon as the lime and ore are all charged, but not before. It is almost as big a mistake to charge the molten iron before all the lime and ore are charged as it is to wait too long afterwards. A good deal of its efficacy is lost. Also, there is a danger of the hot metal breaking through the tap-hole.

To avoid tap-hole trouble, a box of small scrap should always be charged first. This covers the hole and prevents the dolomite and coal stopping from boiling out. Lime only on the hole may stop there and cause that bug-bear of all melters, a hard hole. Fluorspar should never be used to flux lime and ore during melting, as the probability is that it will attack the banks and be the cause of a dangerous boil commencing.

To get the best elimination of phosphorus and sulphur during melting, all the slag should be retained until the bath comes on to boil and the slag shows signs of going thin. Then it can be tapped off and a fresh slag made. A lot of good useful slag is wasted if it is tapped off too soon. In the Talbot process also much useful slag can be wasted if too violent a reaction occurs during charging, some operators thinking that the bigger the commotion the better the result will be, but this is not so, and much better results in time and yield can be obtained by using iron lower in silicon and pouring in the metal in two or three portions, so that the reaction is slowed up somewhat and the slag not all ejected out of the doors.

In the Hoesch process, of course, all the slag should be retained and tapped off with the charge at the end of the first period. Then an entirely fresh slag is made when the charge is put back. In this way only, on the lines indicated, can the best use be made of the materials charged and full value obtained for the money spent on them.

Another thing which is often overlooked is the relation of the quantity of lime and ore required to the silicon content of the mixer or blast-furnace iron. In some hot-metal shops very haphazard methods are used, and in others no method at all, for regulating the consumption of lime and ore. The same amount goes in every time, regardless of the silicon content of the iron. There should be no room in any melting shop to-day for management such as this. Every effort should be made to reduce expenditure by carefully calculating the amount of materials necessary for every separate charge. As the mixer iron varies in silicon content, so should the charge be regulated, and if a ton or two of lime or ore can be saved, it often means quite an appreciable amount of £ s. d. off the monthly cost. A good plan is to have a table made out showing at a glance the exact amount of lime, limestone, or iron-ore required for any given silicon content of the iron being used. Such a table is appended, in the hope that it may be used to some advantage.

Finally, there is the question of charging electric furnaces. In refining crude steel, the lime should be shovelled in at the same time as the liquid is being poured in. If it is charged first, on the bottom, there is a danger of some of it sticking there and not melting up. This soon causes the bottom to become too high, reducing the capacity of the furnace. If the lime is put on top of the charge there will be difficulty in arcking until some of it gets melted up. In 100% scrap charges the lime should never be thrown on top of the cold scrap, as, if this falls under the electrodes, it insulates them and causes delay in melting. It is always best to wait until the charge is half melted, and then put in the lime, taking care to keep it away from the electrodes as much as possible. If the charge can only be put in in two portions the lime should be charged after the first round of scrap is nearly melted. For the same reason, when pig iron forms part of the charge, it should never be put on top, but thrown into the previously melted scrap. In melting scrap in electric furnaces, most of the heat is localised immediately under the electrodes. Pools of steel form here, while the scrap round about, if left untouched, remains unmelted for some considerable time. Much time can be saved by pushing unmelted scrap under the electrodes. This not only saves time, but it also saves the bottom, because, if there is only a shallow pool of liquid between the electrode and the hearth, the great heat localised in that spot will soon cause a hole to appear. To preserve the bottom, therefore, and to ensure quick melting, it is always essential to lift up the electrodes as pools of liquid form, and push more scrap underneath.

This concludes my selection of errors of charging and melting which are committed every day in some works or other. I sincerely hope that the publicity here given will be the means of wiping them out altogether. It is only by carefully eliminating all possible sources of loss, and endeavouring to gain as much as possible, even in small things, that we can hope to successfully carry on in the face of the strenuous and often unfair foreign competition which exists to-day. And I must say that if we would only put our own house in order foreign competition would not be the bogie it appears to be.

CHARGING TABLE—MIXER IRON.

Silicon, %	1·75 to 1·50		1·49 to 1·25		1·24 to 1·00		0·99 to 0·75		0·74 to 0·50		0·49 to 0·25	
Weight of Charge in Tons.	Limestone	Iron Ore.	Limestone	Iron Ore.	Limestone	Iron Ore.	Limestone	Iron Ore.	Limestone	Iron Ore.	Limestone	Iron Ore.
	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.	Cwt.
45	148	242	143	236	137	230	127	219	118	208	112	197
40	132	215	127	210	122	205	113	195	105	185	100	175
35	116	188	111	184	107	180	99	171	92	62	88	153
30	99	161	95	158	92	155	85	147	79	139	76	131
5	17	27	16	26	15	25	14	24	13	23	12	22
4	13	22	13	21	12	20	11	19	16	18	16	17
3	10	16	10	16	9	15	9	15	9	14	8	13
2	7	11	7	11	6	10	6	10	5	9	5	9
1	3	5	3	5	3	5	3	5	2	4	2	4

Table for calculating at a glance the amount of limestone and iron ore required for any weight of charge of Molten Iron, according to the varying Silicon content. For estimating Burnt Lime take two-thirds of the weight of Limestone indicated.

Refractory Materials

Part II.

Examination of Refractories in the Laboratory.

By Colin Presswood, Chief of Technical Department, General Refractories, Ltd.

Chemical Analysis.

THIS is one of the oldest tests, but is by no means sufficient guide to the service value of a material. The results are usually expressed as percentages of various metallic oxides, one or two of which predominate and impart the characteristic heat-resisting properties. The rest are theoretically undesirable, and act as fluxes, diminishing the refractory qualities. Some fluxes may, however, be vitally important in consolidating the mass, and as "catalysts" in the physical changes which take place when refractories are heated. Modern research has shown the great importance of this aspect, though it has long been realised that in the manufacture of burnt refractories the presence of some small amount of fluxes is essential if the manufacturer is to produce, at commercially usable temperatures, a thoroughly burnt mass.

The limits of chemical analysis are apparent when it is realised that heat-resisting materials are usually mixtures of various minerals, so complex that two identical analyses may correspond to two widely different mineral assemblages. Thus, there has arisen a method of calculating, from the "ultimate" analysis, a rational or proximate or mineral analysis. The method is somewhat arbitrary, and should properly be coupled wherever possible with microscopic examination. After indicating that the percentage of fluxes is reasonably low, chemical analysis will relate a material to its class—acid, neutral, or basic,—and is a wise preliminary to the physical tests which are detailed below. Various attempts have been made to connect by formulæ the percentages of desirable and fluxing oxides in a material with its refractoriness. Whilst interesting, these are of doubtful value in ordinary examination.

The chemical characters of the commoner materials will be detailed later under specific headings.

Physical Tests.

Refractoriness.—A term which now includes in its broad sense much more than mere resistance to melting under heat. For test purposes, however, it has a comparatively narrow significance, and means a temperature at which a material becomes so soft that it loses its shape. (The test being made on a moulded piece.)

A definite melting point is a characteristic of, and a test for, a pure material, and as refractories are not pure, it is not surprising that they rarely possess this feature. The constituent minerals are also subject to changes other than melting, as they are heated and may recrystallise. Each possesses its own melting point, and the fluxing minerals present may begin to soften at temperatures lower than 1,000° C. As will be mentioned later, this may have advantages. Such materials are present in such small quantities, however, that their softening does not generally lead to collapse of the whole body. As they melt they may dissolve part of the still solid particles, forming a solution from which new minerals may crystallise. At their melting point they may, moreover, react with other minerals to produce new ones.

As temperature rises, one mineral after another softens. Then comes a point at which the refractory material—which may be conceived as highly refractory coarse particles surrounded by a "matrix" of finer and less refractory particles—owes its rigidity to the former, the matrix being a viscous liquid. Obviously, the viscosity and surface tension of the molten or semi-molten matrix is vitally important. Refractory bricks may be rigid, and, in fact, capable of resisting high crushing stresses at temperatures well above that at which the matrix has begun to melt. Viewed broadly, the viscosity of the matrix will decrease as the temperature rises (neglecting for the moment chemical reactions and recrystallisations in the matrix), and there will come a point at which viscosity is so low that a moulded shape will collapse under its own weight.

It will be seen, therefore, that the definition of refractoriness is by no means a simple matter, and the index tends to be purely arbitrary. The shape and size of the specimen, as well as its position and the rate at which it is heated, are vitally important. Of equal importance is the type of gaseous atmosphere surrounding the test piece during heating, whether oxidising or reducing. Standardisation is therefore essential.

Seger Cone Test.

By far the simplest and most familiar test is that evolved by the German ceramist, Seger, and known as the cone test. In this the specimen to be tested is moulded into a pyramid about 2 in. high, standing on a triangular base, with ½-in. sides, one edge of the pyriamid being, ideally, perpendicular to the base, and the test piece being set on a refractory slab so that this edge is vertical. As the temperature rises and softening develops, the tip of the cone will become rounded, indicating "signs of fusion." Ultimately, the piece loses its rigidity and begins to bend, and when bent so far that the tip touches the base on which it stands the temperature is measured.

Whilst this test is not fully standardised, and results are therefore somewhat at variance, it is commonly conducted with a temperature rise of 50° C. per 5 mins. in oxidising atmosphere (see Gas Engineers' Specification). Clearly, there may be considerable variation in results reported by different testing authorities, some naming the temperature at which signs of fusion occur, others that at which bending begins, or that at which the cone is completely squatted.

Seger's work was directed towards temperature measurement, or, more accurately, measurement of heat-treatment. By carefully blending pure minerals and oxides, such as china-clay and feldspars, he devised a series of standard mixtures (since extended), each given a number. It is claimed that a batch of standard cones bearing the same number will all bend to the same extent if given the same heat-treatment (as to rate of heating, temperature, atmosphere, etc.). The temperature at which each standard cone bends has been measured and can be applied with discretion, but they are properly intended to measure heat-treatment. They are widely used in controlling the firing of kilns of bricks and pottery.

Accordingly, when specimens are tested for refractoriness, a range of standard cones is included in the furnace, and when the test cone is bent the number of the standard cone similarly bent is noted. The range of standard cones is so selected that some are completely collapsed, and others (higher numbers) are rigid and upright when the test piece is fully bent. The test piece is said to have a refractoriness of cone N, the approximate temperature in ° C. being added. To make clear that tests have been made by comparison with standard cones, the American practice is to refer to "the pyrometric cone equivalent," or "P.C.E." of a specimen.

A test such as this can readily be applied to cements, pastes and compositions, raw clays, etc., but needs careful consideration when applied to burnt bricks and shapes. Preferably, a test cone should be cut from the brick, a

tedious and difficult process, which has led to a practice of grinding part of the brick and re-moulding a cone from the ground material. A third method is to heat a part of the brick until the edges and corners show rounding or signs of fusion. In a few cases bricks are heated until they begin to squat. If standardised, any of these might be satisfactory, but it is unfortunate that comparisons have to be made on results obtained by different methods. In particular, the grinding and re-moulding method meets with serious objections, because refractoriness depends to a marked extent on particle-size. (In general, the finer a material is ground, the lower will be its refractoriness.)

The Influence of Atmosphere.

The influence of atmosphere has been closely studied, a good example of its importance being that of refractory materials containing iron oxides. In reducing atmospheres the cone refractoriness may be 100° C. lower than in oxidising atmospheres, this being a generally accepted principle. The explanation lies in the fact that whereas ferric oxide is relatively inert and refractory *per se*, the ferrous oxide to which it gives rise after partial reduction, readily combines with silica to form easily fusible silicates. This effect may be due more particularly to hydrogen and carbon monoxide, but may also be encouraged by steam, which can apparently act either as oxidiser or reducer. The nitrogen of the atmosphere appears to have little effect, although sulphurous gases are harmful.

It is not to be assumed, however, that the above simple explanation of the effect of iron oxides in reducing atmospheres is completely satisfactory, as curious anomalies exist (see later, under iron oxide on silica bricks).

Owing to the viscous nature of the " melt " formed at high temperatures in refractory materials, test pieces will retain their shape, although so soft as to yield when touched. Bricks such as magnesite and chrome may retain their shape up to 1,800° C., but are so soft that a bar of iron may be pushed into them. The same applies to test cones. The changes taking place in matrices are so complicated and may have such effects on the rigidity of the test piece that this test cannot be said to correspond to conditions under which the materials are used. Nor is it completely satisfactory as a means of comparing utilities of several materials.

The outstanding difference between test conditions and those of service is that refractories, when in use, have to bear loads—they are built into massive walls and blocks, and in most cases have to carry the weight of a furnace charge. In addition to this *external* load, made up of the weight of refractory itself and that of the furnace charge, there is an *internal* load, due to expansion stresses. Since melting points are affected by imposed loads, and in order to reproduce more accurately furnace conditions, there has been evolved the under-load test for refractoriness, which is applied most usually to bricks, as these form the most widely used units for building load-bearing structures.

The Under-load Test.

In this the test piece, carefully cut, is heated, whilst it carries a constant load which, in this country, is standardised at 50 lb. per sq. in. The test piece is of the order of 3 in. high by 2 in. square section. The rate of heating is 50° C. per 5 mins., and the temperature at which the test piece collapses is measured either by pyrometer or by Seger cones placed in the vicinity. In view of the foregoing considerations, it is not surprising to find that the " under-load refractoriness figure as given by this test may be as much as 200° to 250° C. lower than the ordinary figure. A magnesite brick, which when heated alone retained its shape to well over 1,800° C., collapsed under 50 lb. per sq. in. at 1,600° C. Most fireclay bricks are characterised by this feature, and show wide differences between ordinary and U.L. refractoriness.

There is still some little misunderstanding on the part of users, who occasionally contrast the high ordinary test figure on one brick with the U.L. figure for another without realising the nature of the test. To reproduce actual furnace conditions in the laboratory, it would be necessary to build a small-scale furnace and work in it a small charge. This is now a practice, but can only be described as a test for refractoriness in its broad sense, including slag action, spalling, etc. The under-load test has been carefully examined, and has been the subject of a good deal of research work, it being now established as a very useful guide to the utility of a material in furnace construction. It is rarely that the external load applied to furnace refractories reaches so high a figure as 50 lb. per sq. in., but this figure is used for test purposes as being one which will cover possible internal loads too. These are, of course, difficult to measure.

In the close investigation of refractory materials, it is not sufficient to consider this test as giving merely the temperature of collapse, as it is capable of much wider use. In the first place, the type of collapse shown by the test piece is worthy of study. It may indicate complete softening or a definite fracture due to mechanical weakness of the bond or matrix between coarse particles. The mechanical type of collapse may take place at low temperatures, and the same refractory material, differently treated in manufacture, may give vastly different results. A material which is really highly refractory may fail at comparatively low temperature in this test, owing to this mechanical weakness. The under-load test furnace is invaluable in research on the manufacture of any line of bricks. In such work various test loads are used, each bringing out different features in the softening process.

The test may be regarded as a crushing strength determination at high temperatures, though there is now a special determination made of such figures, as will be mentioned later.

As the test piece is heated, it may expand, of course, before shrinkage and collapse is reached, and the application of the load is so devised as to maintain constancy in spite of the movements. By careful design it is possible to connect to the pivoted arm through which the load is applied, a recording needle which records on a chart the combined movement of the test piece and refractory thrust rod. This latter is selected for its high refractoriness and even and regular expansion, so that, as far as possible, irregularities in the expansion curves are due to the test piece. Materials such as carbon and silicon carbide are commonly used for thrust rods, thus ensuring that the collapse shown in the curves is due to the test piece and not to the thrust rod.

A study of expansion curves under constant load is certainly of value, and will be mentioned under " Notes on Expansion." The curves show two broad types of collapse, the gradual and the rapid. The former is a rounded curve, the latter being sharp. The former indicates a wide softening range in the material, suggesting that in a furnace it would give warning of collapse if slightly overheated. Most fireclay bricks come under this class. They are generally not good load-bearers at high temperature. In the second class are straight silica bricks which can carry high loads to high temperatures, but the maximum temperature must not be exceeded greatly before rapid collapse sets in without warning.

(References to papers and reports, books, journals, etc., will be given at the conclusion of the section dealing with physical tests).

TRADE GUIDE.

An advance edition of the catalogue of the London section of the British Industries Fair is being prepared with a classified index to goods in nine languages. It will be ready this month and will be valuable to overseas buyers before they leave their homes for the Fair, which is to be held simultaneously in London and Birmingham from February 17 to 28.

Reviews of Current Literature

BLAST FURNACE PRACTICE.

THE concluding volume of this valuable work has just been published, and the expectations referred to in our review of the previous two volumes are more than fulfilled. As we anticipated, this volume deals primarily with the operation of the blast furnace and the subsidiary products, as well as pig iron. The demand for consignments of pig iron of definite brand and grade to maintain an accurate analysis has grown considerably during recent years. The user is prone to blame his raw material for failure in his products. It is frequently asserted that the supply of pig iron with the same chemical composition in every consignment with unfailing regularity would relieve the manufacturer of a very real difficulty. There is undoubtedly much truth in this assertion ; after all, the main function of the blast furnace is to produce pig iron of the right quality, but when the most modern blast-furnace plant is considered, with the material available for producing pig iron, the degree of accuracy in composition of the product is remarkable. Consider the quantity and variability of the raw materials used in the blast furnace : In Great Britain, for instance, the bulk of ore mined is of low grade, averaging approximately 30% of iron, and the ore from different mines has a different geological character. Even from the same mine variations occur. All the raw materials which form the burden in the blast furnace are natural materials, and as such are variable in character. The knowledge available in the investigation of the composition of these raw materials is not sufficient for exact calculation. It is the manner in which the various substances are linked together as compounds that causes difficulties in calculating accurately the constitution of the charge to give a desired result. Mr. Clements does well to stress the difference between this country and America in this respect. The uniformity of quality of the raw materials in the United States has long been recognised as an important factor in good furnace operation. The ore is carefully graded at the shipping points, and materials of varied value are mixed to give a more regular quality.

The slag composition as well as hearth temperature are vital factors in the quality of the product, and irregularities in this respect are frequently the direct consequence of incorrect burdening. The demands of furnace operation do not always permit of exact technical investigation and control. This is particularly true in regard to the quick estimation of the character of slag, for which visual methods are almost invariably used, but the aid of chemical analysis to confirm estimates is equally important. Consideration is given to the value of slag for other purposes. Its profitable use has become a matter of considerable importance, so much so that it is now of economic value to burden the furnace in order to ensure a quality of slag suitable for variety of uses and yet maintain suitable conditions for the pig iron product. Blast furnace slag may be used as ballast for railway lines or for road-making ; it may be moulded in the form of bricks, and, if not too acid, may be burnt in a powder form with lime, to give a cement. Slag wool or silicate cotton is extremely useful as a non-conductor of heat and sound.

The problems that may arise when operating the blast furnace are innumerable, and any attempt to deal with the many phases of these problems would, as the author suggests, be impossible, but the principal troubles have been thoroughly examined, and specific instances of some of the major problems are given from experience. This chapter on operating problems and their solution cannot fail to be of immense value to all directly engaged in blast-furnace operations. The solution of difficulties is not limited to the furnace, but includes faults that may develop in the auxiliaries. Mechanical defects as well as operating troubles arise and must be dealt with expeditiously if the furnace is to maintain constant production.

The human element upon which the success of the plant so largely depends cannot well be omitted. Maintaining the health and well-being of the workpeople is now recognised to have a definite economic value, and Mr. Clements appreciates this fact. He has much to say of the capacity of the men employed, upon which so much depends, and also upon extraneous influences that affect the feeling existing between the workmen and management. He infers that an efficient management is not only concerned with the maintenance of the plant, but also in maintaining a spirit of harmony between workpeople and management that will ensure production on an economic basis.

Development in the utilisation of blast-furnace gas have been delayed owing to difficulties encountered in cleaning to give it the desired efficiency. The presence of dust reduces its value considerably, and to get the best results from a blast-furnace gas engine, it is necessary that the gas be cleaned to a high degree of purity. Many factors are necessarily involved in cleaning the crude gas and in making full use of it, whether for generating electric or steam power or directly in connection with metallurgical or other furnaces. The whole subject of purification and utilisation of blast-furnace gas is authoritatively considered at considerable length, and a special schedule giving comparative data of an international character is supplied.

In addition to further schedules having special reference to ferro-manganese practice, this volume is well illustrated with photographs and drawings, and data tables of a very informative character are used where they are of most value, and form a very fitting conclusion to a valuable work. We take another opportunity of commending the publishers on the excellency of its production, the whole work being an admirable production.

It is well that the author found encouragement and support from the motto of the City of Sheffield, " Deo Adjuvante Labor Proficit," for the work involved in writing such a comprehensive treatise, dealing with all the phases of this complex subject, must have been a prodigious task. We believe this complete work to be the most comprehensive and most important that has been written in the iron and steel industry, and have no hesitation in saying that it will become indispensable alike to operator, engineer, and designer.

BLAST-FURNACE PRACTICE. By Fred Clements, M.Inst.C.E., M.I.M.E., A.M.I.E.E. Volumes I., II., and III. Net price, £3 3s. per volume. Publishers : Ernest Benn, Ltd., Bouverie House, E.C. 4.

THE MANUFACTURE OF CHILLED IRON ROLLS.

THE production of chilled cast-iron rolls has been carried on for generations, and without the use of foundry technique that is available to-day, considerable craftsmanship, combined with sound judgment and thoughtful observation, must have been the characteristic of those who manufactured them before the twentieth century. It is sometimes said, not without considerable truth, that the successful production of chilled rolls demands the highest degree of ability of those engaged in the foundry industry. The use of cast iron for rolls is due to the unique properties possessed by this material. Under the conditions of heating and application of water and scale, chilled iron rolled retains and imparts a good surface to material rolled, probably due, in grain rolls, to the hard aggregate of pearlite and graphite, yet possessing lubricating properties, and the interruptions in structure provide resistance to expansion and contraction cracking. In addition, scale does not bite into the surface so much as in steel rolls, for instance. All rolls are of pearlite iron, and for grain rolls to give good service, both pearlite and graphite must be fine grained to ensure good rolling properties, combined with mechanical strength.

The object of this work is to form a systematic record of a very complicated process which has not been intensively

studied scientifically to an extent comparable with steel. The experimental work involved has been carried out in a maintenance foundry entirely occupied with rolling steel, and which rapidly developed into routine manufacture. Mr. Allison has been personally responsible for most of the technical duties of the metallurgical control recorded in this work. The depth of chill, to some extent, is a matter of individual choice, but all rolls are expected to have sufficient depth to give good life, and yet not too deep to make them brittle. Due to forces present in all chilled rolls, they are subject to casualties that affect their life, and the author makes special reference to the influence of frosty weather, rapid heating, cold ends of the rolled piece, stickers, and defective lubrication of necks, as being some of the causes of damage and destruction.

There is so little useful information available on this particular subject, probably due to the difficulty of combining the supervision of manufacture with a careful record of data, that this work will fill a definite need. The book is illustrated with micrographs, and is well produced, and, to all interested in the manufacture of chilled iron rolls, it will prove a valuable asset.

THE MANUFACTURE OF CHILLED ROLLS. By Archibald Allison. Published by Sir Isaac Pitman and Sons, Ltd., London, W.C. 2. Price, 8s. 6d. net.

FOUNDRY PRACTICE.

THE fact that this is the fourth edition of this book indicates its popularity. The author is an American, and in consequence slight variations in practice and in the terms applied from those that are in use in this country are to be expected. The fundamental principles of foundry practice, however, do not differ. The book is comprehensive, and full of useful information a competent foundryman should know, and it is prepared in such a manner as to be readily assimilated by anyone having a knowledge of foundry practice. It is impossible to acquire the art of moulding by reading a book, as Mr. Palmer rightly states. It is a manipulative art, and continual practice is essential to obtain that degree of proficiency necessary: but information obtained from books such as this supplements what always must be a somewhat limited personal experience. By assimilating varying methods, determining which to follow under certain circumstances is simplified. The book deals more particularly with iron foundry practice, as reference to both brass and steel foundry practice is very brief, and work in connection with the alloys of aluminium is not considered. The examples chosen to assist instruction in green and dry sand moulding are progressive, and the same may be said of the work on loam moulding, although no reference seems to be made to loam patterns, which have considerable economic value in some classes of work in this country. Cast iron and the influence of its components, together with a description of cupolas and their operation, are dealt with fundamentally. In this edition an appendix of considerable length has been added in order to bring the book up to date. It is composed of special articles on a wide range of subjects associated with foundry practice. Mr. Palmer has endeavoured to make a text-book for the student, apprentice, moulder, and a useful work for the general foundryman, and his efforts in dealing with so difficult a subject are undoubtedly praiseworthy. The book will prove of value to all interested in the production of castings.

FOUNDRY PRACTICE. By R. H. Palmer. Published by John Wiley and Sons, New York, and Messrs. Chapman and Hall, Ltd., Covent Garden, W.C. 2. Price 17s. 6d. net.

ESTIMATING.

FORECASTING a reliable estimate of the costs incurred in manufacture is a very exacting business nowadays, and may almost be classified as a science. To carry out the various calculations necessary without overlooking some of the many details frequently involved, a scientific training coupled with a reasonable degree of practical experience are almost imperative. This is particularly true of estimating in engineering manufactures. The time is long past when a rough guess would suffice as a reasonable indication of the cost of material and labour necessary in the production of a piece of mechanism, to which could be added a percentage for establishment charges and the profit. Competition is so keen to-day that accurate estimating has become a necessity, otherwise contracts will be lost, due to the costs being too high, or if the contract is secured at too low a cost a loss on production results. The compilation of estimates is essential to practically every department, and a practical knowledge of the work done in the particular section is a valuable asset to the estimator, while a more complete knowledge becomes invaluable when the estimator is required to prepare the costs of manufacture of a complicated machine, engine, or complete plant. Mr. Hargrave makes the position clear in his book on the subject, the main object of which is to give young engineers an insight into the commercial side of the business, particularly in the preparation of estimates. If one section may be mentioned more than another it is the foundry, in a large percentage of which estimating is in a chaotic state. The old system of costing by weight still exists. On the balance of work done the estimate may be quite in order from the foundryman's view point, but the complicated castings will work out cheaper than the heavier castings with relatively less work on them. With proper training on the subject, the foundry is gradually coming into line with other departments by preparing estimates from cost of material needed, cost of labour to do the work, and cost of overhead charges. The subject of estimating is a comprehensive one and difficult to condense into 118 pages, the book is, however, well prepared and illustrated, and, in addition to the young engineer, for whom it has been specially written, it contains much that will be of value to draughtsmen, costs clerks, foremen, and works managers.

ESTIMATING. By T. H. Hargrave. Published by Sir Isaac Pitman and Sons, Ltd., Kingsway, W.C. 2. Price, 7s. 6d. net.

CATALOGUES AND TRADE PUBLICATIONS.

Foundry managers, metallurgists, and manufacturers of malleable castings will find considerable interest in the brochure recently published by the Workington Iron and Steel branch of the United Steel Companies, Ltd. It contains notes of the various brands of pig iron made at the Cumberland works, together with some excellent photographs of positions and complete analyses of all grades. Copies of the publication (W 109) can be obtained on request from the Publicity Department, the United Steel Companies, Ltd., Sheffield.

The Zinc Alloy Rust-proofing Co., Ltd., have recently published an interesting brochure on Sherardising. This is a process of heat-treatment which results in the formation of an alloy of zinc and the metal under treatment. Interesting particulars for preventing rust are referred to in the brochure, which can be obtained on application to the above company at Shakespeare Street, Wolverhampton.

The use of special steels having the characteristics that fit them for special duties is now fully recognised. One of the many having outstanding qualities is the Firth "Staybrite" steel. Its main characteristic is its resistance to corrosion. It is both ductile and malleable, and can be worked cold. Much information respecting this special steel is now published in a brochure, which can be obtained on request from Thomas Firth and Son, Ltd., Sheffield.

We have received a copy of The Nickel Bulletin No. 5, containing a special article on "Nickel Alloy Steels in the Daimler Double-six." An additional feature of an informative character is the abstracts of papers in which reference is made to the use of nickel for a wide variety of purposes. A copy of this bulletin will be forwarded to any one who is interested on application to The Bureau of Information on Nickel, bhe Mond Nickel Co., Ltd., Imperial Chemical House, Millbank, London, S.W. 1.

Some Recent Inventions.

IMPROVING, FORGING AND UPSETTING MACHINES.

IN forging or upsetting machines the whole surface of an article is usually operated on at once by squeezing the material between the dies. Such methods involve high peak loads, and strains are produced necessitating extremely strong, heavy, and expensive machinery. A new device for forging, upsetting, or rolling circular work reduces the maximum pressure required at any one time, and enables lighter and cheaper machines to be used. The motion of the new machine is so arranged that different parts of the dies come successively into operation, producing a kind of rolling effect so that high pressure is produced only over part of the surface at once. In Figs. 1 and 2 front and side elevations of an improved machine are shown. The upper

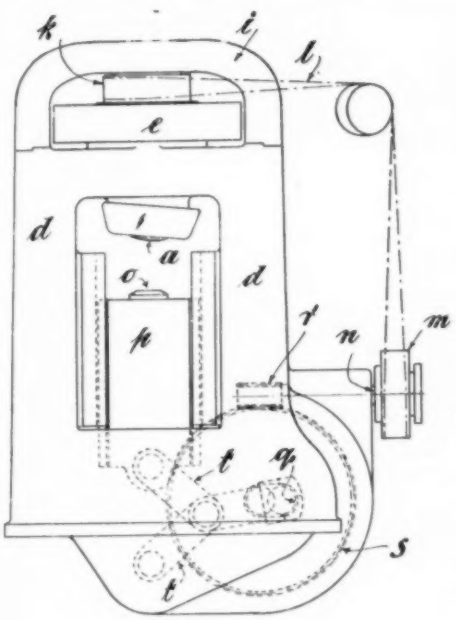


Fig. 1.

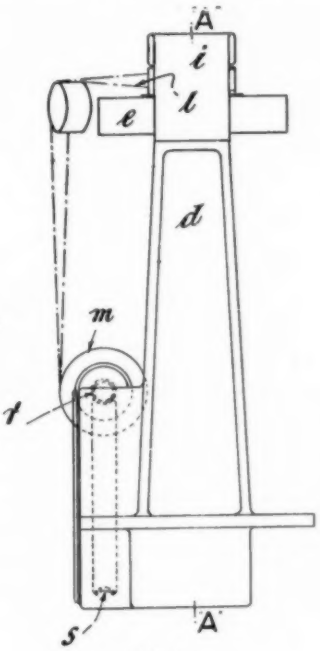


Fig. 2.

die receives the circular rocking motion and the lower die is moved up and down on the table by the crank, which is put in motion by a clutch arranged to stop when the table is in its lowest position. A vertical section taken on the plane indicated by the line A A of Fig. 2 is illustrated in Fig. 3, but is in a larger scale to show the arrangement of the upper part of the machine to better advantage. The upper die A is fixed to the lower surface of the die-holder B, which has a surface of spherical curvature on its upper side, allowing it to rock in a part C attached to the frame D of the machine. Above the die-holder and co-axial with it is a wheel E which can be revolved by power about a vertical axis. A central stem or projection F extending upwards from the die-holder enters the eccentric hole in this wheel, and the die-holder is pressed by any suitable means. In this instance, the die-holder is held up by a plate G secured by a set-screw to the stem of the die-holder, and the wheel is provided with upper and lower sleeve-like axles made to revolve in bearings in the frame D and the upper frame, secured and supported by ball-bearings J applied below the lower axle. As the wheel E is revolved mechanically, motion is transmitted to the die-holder, causing the top die to rock with a regular circular or rolling motion about the spherical surface. The bottom die O is fixed to a table P, which is capable of vertical movement by means of the crank Q, power being transmitted by a worm and worm-wheel from the shaft N. Motion is controlled by a foot lever operating through a clutch. During the upstroke the forging is lifted on the die and pressed against the upper rocking die, the upward movement co-operating with the circular rocking movement to upset and mould the metal into the shape governed by the dies.

This improved forging or upsetting machine is designed for making circular articles, such as wheel blanks, spur-wheels, bevel-wheels, articles of an irregular form, and for drawing down plain sections or for other analogous purposes, in which dies are so formed.

319,065. Messrs. B. and S. MASSEY, LTD., and H. F. MASSEY, of Steam Hammer Works, Openshaw, Manchester. Patentees: Howard Cheetham, agent, Manchester. Complete specification accepted September 19, 1929.

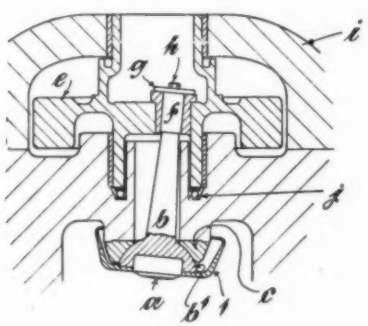


Fig. 3.

IMPROVED STEEL SLEEPER.

AN improved steel sleeper was shown at the recent International Exhibition of Inventions held in London. Incorporated in the new design are four oval holes through the sides of the sleeper. This improvement will overcome one of the disadvantages previously experienced in the maintenance of steel-sleepered road. The holes facilitate packing operations, enabling small ballast to be inserted to form a complete core in the inverted trough. Formerly packing steel sleepers efficiently has always been a difficult problem, but with the new arrangement, when it is necessary to raise a depressed rail to its former level, or pack a sleeper which has become loose on its bed, the additional ballast can be forced through the holes to the top of the core. It is claimed for this design that the packing is more effectually done than by former methods and no disturbance of the ballast alongside the sleeper is necessary. These slots can easily be applied to all known types of steel sleepers without materially affecting the first cost. Mr. Tom Davies, who has considerable experience of railway permanent way work, is responsible for the invention.

FACING METAL BODIES BY WELDING.

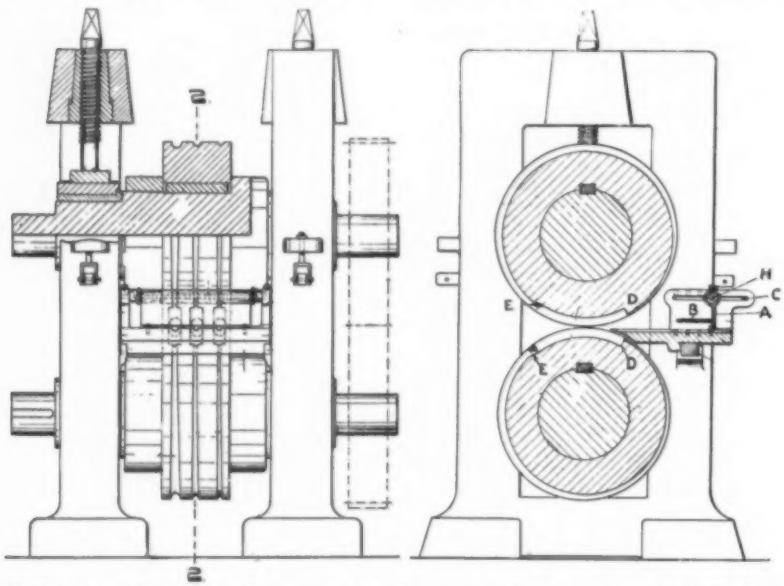
IN order to provide metal bodies, such as earth boring drills, with a hard metal facing a granular composition of tungsten and carbon is applied, and fused by electric arc-welding. The composition may consist of 9 lb. of powdered unwrought tungsten, 1 lb. of finely divided carbon, together with a binder, such as 1 oz. of dextrine. These ingredients are mixed in dry condition and dextrine water added to form a paste, which is dried and baked in an oven and then broken into small particles. In use the tungsten alloys with the carbon to form tungsten carbide, and also alloys with the metal body. Part of the carbon is burned during

welding, and serves as a reducing medium to prevent oxidation of the tungsten. A number of layers may be applied in succession. It is stated that the tungsten may also be used in the form of a welding rod, and that elements such as nickel, uranium, molybdenum, manganese, vanadium, titanium, chromium, or tantalum may be used in addition to or as a substitute for tungsten. It is further stated that other ingredients may be used in addition to or as a substitute for carbon.

P. L. and M. Co., 215, West 7th Street, Los Angeles, U.S.A.—(Assignees of Morgan, H. J.; 2830, East Broadway, Huntingdon Park, California, U.S.A.) Feb. 8, 1929.

IMPROVEMENTS IN MANUFACTURING HOLLOW METAL BARS.

IN making rock drills from hollow bars it is desirable to make the stem, between the shank and the cutter-head, of a different size or shape from the shank, and a tapering



of the stem by a swaging operation is proposed. The hollow tube is filled with sand or some ductile metal to support the steel in the rolling operation. When rolling tubes, with the aid of a mandrel or tapered bars, between grooved rolls, a wider portion, providing a gate of greater cross-section than the work, is followed by a tapered or narrowed portion, which extends to a junction with the other end of the wide portion. A new method is to have a stop in front of the rolls to determine the distance to which the work is to be introduced, between the gaps formed by the wider portions of the grooves and to provide a table or plate in front of the walls to support the work. In order to avoid variations and to enable bars containing a ductile core to be rolled into rock-drill lengths, the rolls, being of desired shape, have a movable gauge fitted at the rear, so that the rolled bar passed through the gate and held in position by the operator, until the tapered portions of the grooves come into operation, will be forced through the rolls, displacing the gauge provided. The movable gauge may be provided by a pivoted plate held by a spring against a stop opposite the pass or all the passes of the rolls, the spring and stop being arranged so that the pivoted plate is movable against its spring away from the rolls. It is preferable that the gauge-plate be adjustable in order that the length of the shank may be varied. Figs. 1 and 2 illustrate the type of machine suitable for rolling hollow tapered rock drills. Each groove in the rolls provides a gate of sufficient area for the passage of the rolled bar. The wider portion extends for the desired distance to form the shank, from D to E, and then tapers around the rolls to a junction with the end D.

At the rear of the rolls is the backing-plate, which is grooved to support the rolled rod centrally. A movable gauge-plate A is fitted at the back and is controlled by spring B, the gauge being pivoted between brackets. The spring holds the gauge in contact with a stop. The use of slotted brackets C enables the ready adjustment of the gauge. The movable gauge-plate extends opposite to all the passes in the rolls, and, in operation, the length of rolled bar is passed through the gate formed for the wider portion. The length of bar is forced through the rolls in the usual way, it being understood that the bar is successively operated on by the various grooves in the rolls, these grooves being arranged gradually to augment the desired taper formation. The rolls should be marked to indicate when the bar is to be inserted.

319,934. R. A. BEDFORD and J. KENDRICK, both of Sheffield. Patentees: A. H. Greenwood, agent, 39, Bank Street, Sheffield. Complete specification accepted October 3, 1929.

ARC-WELDING ELECTRODES.

AN arc-welding electrode is made by twisting a flat metallic strip of rectangular cross-section into helical form, and extruding between the turns a coating of fluxing materials, and/or slag-forming materials, with or without powdered metals or alloys. The extrusion die may closely fit the turns so as to obtain an electrode in which the outer edges of the turns are free from the coating, and thus rendered suitable for use in an automatic-welding machine, or the die may be larger than the helix so as to form a coating over the outer edges as well. The electrodes may be used for welding iron or steel, copper, brass, bronze, aluminium, or aluminium alloys. Specification 127,315 is referred to.

319,487. ALLOY WELDING PROCESSES, LTD., and CLARKE, E. J. 14, Cockspur Street, Charing Cross, London, September 20, 1928, No. 27019. Drawings to Specification. (Class 83 (iv).)

REFINING AND ALLOYING IRON AND STEEL.

A BRIQUETTE for refining and alloying molten iron or steel consists of a ferro alloy, which may be ferrosilicon, ferromanganese, ferrophosphorus, ferrochromium, ferrovanadium, or ferrotitanium, soda ash and a lime cement. The powdered cement is mixed with the crushed ferro alloy and the soda ash then added, the mixture being made into a paste with water, pressed into briquettes and dried. Examples are given of mixtures of 150 lb. ferrosilicon, containing about 45% of silicon, 15 lb. cement, and 10 lb. soda ash; 180 lb. ferromanganese, containing about 30% manganese, 15 lb. cement, and 10 lb. soda ash; and 191 lb. ferrophosphorus, containing about 20% phosphorus, 15 lb. cement, and 10 lb. soda ash. The soda ash acts as a desulphurising agent, and by making the briquettes of definite composition any desired amount of alloying element may be introduced into the iron or steel.

319,603. CASTLE, G. C., WOOD, C., and BEECROFT AND PARTNERS, LTD., St. Peter's Close, Sheffield, June 22, 1928, No. 18112. (Classes 72 and 82 (i).)

REFRACTORY SUBSTANCES.

A ROCK primarily composed of a hydrated silicate of magnesia, and known as serpentine, is made suitable for use as a refractory material by being calcined at a temperature high enough, about 2,900° F., to drive off its volatile constituents and reduce its porosity below 20%.

Business Notes and News

The Sale of a Sheffield Monument.

The sale of the Bessemer Steel Works, of Sheffield, is a regrettable break with steel-trade tradition. These works have been for years a reminder of the valuable contribution to the science and practice of steel-making which Henry Bessemer made when he discovered the process which bears his name. His discovery of converting fluid cast iron into steel by forcing a blast of air through it revolutionised the steel industry of the whole world and brought valuable business to Sheffield, particularly of railway materials. It may be mentioned that Bessemer's discovery did not yield the desired result at the outset and he was to a considerable extent discredited, but he persevered, and ultimately perfected his invention and produced steel from his own works at £20 per ton less than the trade generally. His pertinacity was rewarded and he rehabilated himself, becoming a power in the steel-making industry.

Rationalisation in the steel trades caused the purchase of the whole of the shares in Henry Bessemer and Co. by John Baker and Co., of Rotherham, and the combined concern is now operated by John Baker and Bessemer. Evidently it is considered that the work can be carried on more profitably at the works of the new company, chiefly at Kilnhurst, accordingly the Bessemer works, Sheffield's monument to one of its great steel inventors, has come under the hammer.

Bridging the Zambesi.

The proposed bridge over the Zambesi River, mentioned in Mr. Thomas's speech on schemes for unemployment, which will give through rail connection between Beira and Nyasaland, will be the largest job of its kind ever undertaken in Southern Africa. The design has already been prepared by Messrs. Rendel, Palmer, and Tritton, consulting engineers, Westminster, and shows a bridge 12,000 ft. long, made up of 33 spans, standing sufficiently high above normal water level to permit the passage of river craft beneath it. The point at which the bridge is to be erected will be Sena, which will necessitate an approach line on the south bank from Murraca. On the north bank the connecting link will probably run into Bahwe cutting, necessitating a total amount of 28 miles of approach lines. The estimated cost of the bridge is £1,500,000. The Central Africa Railway Company have already commenced work on the north approach line. It now only remains for the Nyasaland Government to make the final financial adjustments. Tenders for the work will no doubt be invited in the near future.

Organising the Selling of Farm Machinery.

A combined effort is being made to place British and Empire manufactured agricultural machinery on a large scale in the markets of the world. The scheme, according to Mr. G. E. Rowland, chairman of Agricultural and General Engineers, Ltd., will cover the manufactures of the engineering group of which he is chairman, those of another important British firm, and of the greatest Australian engineering concern, thus initiating an important forward step in consolidating the manufacturing resources of the Empire in a combined offensive on the world market for agricultural machinery.

An analysis of the world's exports of this type of machinery shows that almost 75% of the world's trade in these products is in tractors and harvesters. Our inability, previously, to supply the complete range of machines required by overseas farmers has been the main reason why the trade in these products has been to so large an extent controlled by foreign competitors. The present scheme removes this handicap and places the group in a more favourable position to obtain an adequate share for Great Britain of this very important trade.

Williams' Prize Award.

The Williams' Prize of the Iron and Steel Institute, of the value of 100 guineas, has this year been awarded by the Council to Mr. William E. Simons, Assistant Blast-furnace Manager, at the Cardiff works of Messrs. Guest, Keen and Nettlefolds, Ltd., in consideration of his paper on "The A.I.B. Sinter Plant at the works of Guest, Keen and Nettlefolds, Ltd.," which he presented at the last annual meeting of the Institute in London.

The "Macrome" Steel Process.

A recent process applied to finished steel products of any analysis—whether a straight carbon or an alloy steel—is claimed to increase its endurance. The process is carried out by Messrs. Grist and Co., 50, Summer Row, Birmingham, and is known as the Macrome process. The process applied to the finished article varies according to the contents of the steel of which it is manufactured, its heat-treatment history, and the purpose for which it is made. The chemical contents of the steel to which the process is applied remains unaltered, and the temperatures, under which the treatment by this processs are carried out do not affect the heat structure existing in the finished product. Its aim is not to alter these structures, but to change the substructure to enable them to resist the stresses set up in work for a longer period of time without breaking down. Treatments by this process have been standardised for small tools, both carbon and high-speed steels, including drills, milling cutters, slitting saws, turning tools, hacksaw blades, etc. Mining tools, files, rails, and a wide variety of steel products, subject to excessive wear or stress, are claimed to be improved to a very considerable extent by the process, giving greater uniformity to the steel, increased resistance to varying stresses and to vibration, reducing the liability to crack or fracture under normal working conditions and increasing resistance to erosion.

Subsidiary Furnace Company Formed.

The Electric Furnace Co., Ltd., of 17, Victoria Street, London, S.W., has formed a subsidiary company to cope with the demand for resistance furnaces for industrial purposes. The new company will be known as the Electric Resistance Furnace Co., Ltd. It will deal with all installations of EFCO resistance furnaces and stoves, now being used for heat-treatment of ferrous and non-ferrous metals and alloys, enamelling and japanning, decoration of pottery, glass annealing, core drying, etc. The benefits of patents and agreements for exchange of technical information and drawings with foreign countries, in so far as they apply to resistance furnaces, will be transferred to the new company. The parent company will continue to supply Herould, Ajax-Wyatt, and Ajax-Northrup furnaces, and contract for complete metallurgical and electrical installations.

Steel Trade Rationalisation.

Developments are foreshadowed in a circular recently sent out by John Brown and Co., of Sheffield. Shareholders have been informed that it is proposed not to pay an interim dividend on the company's shares. The board have under consideration certain measures for the rationalisation of the business of the company and this appears to be the reason for not paying the dividend. As soon as these measures are completed they will be submitted to the shareholders. This company was formed sixty-five years ago and the authorised capital is £5,000,000. It is interested in shipbuilding, wagon-building, coal and iron-mining, steel-making, etc.

Manchester and District Iron, Steel and Allied Trades Celebrate.

It is interesting that hard-headed business men of the North engaged in the iron and steel industry can meet together for a convivial evening and have an excellent time together. This celebration represented the twentieth annual dinner of the Manchester and District Iron, Steel, and Allied Trades Bowling Club, held at the Engineers' Club in Manchester, on Saturday, December 7. The function was typical of a gathering of friends, who enjoyed an efficiently served dinner under the presidency of Mr. A. McMurdo. In the speeches that followed, the first serious note was struck by Mr. H. C. D. Scott, who, in proposing the toast of the industries covered by the association, spoke of the progress made in recent years, in which the association had shared. He remained an optimist, and believed that the durable service of British products would always give them a reasonable place in the world's markets. In responding to the toast, Mr. W. H. Flanagan stressed the need for rationalisation. He suggested little could be done individually, but by combining and determining weaknesses in our system of marketing the solution of difficulties would be facilitated. He touched on somewhat delicate ground when he confessed to being a Free-trader, but with safeguards to ensure some degree of equality of opportunity in trade. The harmony of the evening terminated with a word of high commendation for the Secretary, Mr. R. A. Miles.

Some Contracts.

It is reported that the New South Wales Government Dockyard at Walsh Island, Newcastle, which had a record turnover last year, has in hand already £100,000 worth of contracts for the current year. These include eleven miles of steel pipes for the Broken Hill water supply scheme, 11½ miles of steel pipes for the Southern Tablelands water supply scheme, and a large quantity of pipes for the Sydney Water Board. There are other contracts in view which, with those mentioned, are expected to keep the works during the next twelve months at the high pitch of activity reached last year. The new floating dock will be available for docking purposes next month, and this will mean much additional work for the staff.

The Compania Italo Argentina de Electricidad, Buenos Ayres, have placed an order with Babcock and Wilcox, Ltd., London, for eight C.T.M. water-tube boilers, each having a normal evaporative capacity of 50,000 lb. of water per hour. All are oil-fired, but two will also be fitted with Babcock and Wilcox chain grate stokers for burning coal. The others are so arranged for conversion in this respect with a minimum of constructional alteration, if so desired. The order amounts to over £300,000, and the whole equipment will be manufactured at Babcock and Wilcox's works at Renfrew, Scotland.

The Underfeed Stoker Co., Ltd., Derby, have secured an order for six Schenck-Heymann vibro-conveyers from Imperial Chemical Industries. The conveyers are of special design, and are capable of handling fine cement dust at a temperature of approximately 400° C., with capacities up to 30 tons per hour. We understand that a further conveyer of this type has also been ordered for use as a combined conveyer and screen, its capacity being 100 tons of limestone per hour.

We are informed that the Department of Posts and Telegraphs, Wellington, New Zealand, have placed orders with S. Smith and Co., Manchester, for 25 tons 70-lb. bronze wire and 110 tons 40-lb. bronze wire, at a cost of over £15,000; and with Thos. Bolton and Sons, Ltd., London, for 80 tons 200-lb. copper wire and 24 tons 150-lb. copper wire, at a price of nearly £10,000. The latter firm has also recently been awarded a contract for telegraph material for the Egyptian State Railways.

It is reported that the contract for the heightening of the Assuan Dam has just been placed with Norton, Griffiths and Co., and work will begin as soon as possible.

The following tenders were submitted:—Norton, Griffiths and Co., Ltd., London, £E1,958,378; Sir John Jackson, Ltd., London, *£E2,521,949 (*less 1½%); Netherlands Harbour Works, Holland, £E2,569,263; Julius Berger, Germany, £E2,574,837; Societa Adriatica, Italy, £E2,532,172.

Among some contracts placed by the Egyptian State Railways are the following: J. Stone and Co., tin ingots, £E3,861; Metropolitan-Vickers Company, Manchester, high-tension switchgear; Westinghouse Brake and Saxby Signal Company, signalling material; Steel Company of Scotland, carriage and wagon tyres; Ibbotson Bros., Sheffield, steel files.

The Southern Rhodesian Railway, it is reported, has just placed the following orders in Great Britain: 5,200 tons of steel sleepers with Dorman, Long and Co., of Middlesbrough, and Guest, Keen and Nettlefolds, Co., Ltd., Birmingham, for a similar quantity. For the supply of 6,300 tons of rails and fishplates with the Barrow Hematite Steel Company, Barrow-in-Furness. The value of these orders amounts to over £150,000.

Royce, Ltd., Manchester, have received orders for eight 10-ton overhead travelling cranes for a large new motor works; twelve overhead travelling cranes, ranging from 1¼ tons to 40 tons capacity, for use in paper-mills; two 10-ton overhead travelling cranes for an engineering works; two pulp-stacking cranes for paper-mills; one 5-ton overhead travelling crane for a glassworks; and one 7½-ton overhead travelling crane for an iron and pipe works.

Metropolitan-Vickers, Ltd., Manchester, have been awarded a contract by the Victorian Electricity Commission for two 25,000-kw. turbo-alternators, condensers, and plant for the Yallourn Power Station, at a cost of £148,375.

A number of orders for the rolling stock of the Rhodesian railways have been placed with the following firms:—The Birmingham Railway Carriage and Wagon Co., Ltd., Birmingham, have received an order for 100 short drop-sided wagons and six second-class coaches. The Gloucester Railway Carriage and Wagon Co., Ltd., Gloucester, are to supply six first-class coaches and six native coaches. The Craven's Railway Carriage and Wagon Co., Ltd., Sheffield, three third-class coaches. Messrs. Hurst, Nelson and Co., Ltd., Glasgow, ten guards' vans, and the Metropolitan Carriage, Wagon and Finance Co., Ltd., Birmingham, 150 high-sided steel wagons and 150 drop-sided steel wagons, each with a capacity of 45 tons of freight. Tenders are also out for 12 locomotives, each of 120 tons, 100 bogie covered goods wagons, and 50 bogie covered cattle wagons.

Plans for the development of Cork harbour and the establishment of a national free port have been submitted on behalf of Ireland Corporation of New York to the Cork Harbour Board. The estimated cost of the scheme is £1,839,650, which the New York corporation is prepared to advance at a reasonable rate of interest. The plans include the establishment of a free port at Little Island. The financial proposals provide for a subsidy of £300,000 from the Free State Government, including which the total of the potential revenue would be £612,000 a year.

A Government Bill has been introduced into the Northern Ireland House of Commons to constitute the Ministry of Finance a drainage authority for the purpose of drainage of Lough Neagh and the River Bann. The periodical flooding of Lough Neagh, the largest lake in the British Isles, has been a source of considerable loss to farmers on the shores of the lough and the River Bann. Thousands of acres are flooded annually and their crops destroyed. The Government proposes to enter upon a comprehensive drainage scheme which may cost over a million sterling, and to which the councils of the counties adjoining the lough will contribute.

The Soviet Government, we are informed, is deputing a commission to visit England shortly to negotiate the purchase of textile machinery to the value of £1,000,000.

The Southern Railway is seeking Parliamentary powers to carry out several important schemes. These include improvement of the exits at City Station on the Waterloo and City Railway; the construction of a new electric railway about seven miles long towards Leatherhead; and the widening of the Hounslow loop line.

According to the "Ekonomicheskaya Zhizn," the Soviet Government proposes to construct 7,280 miles of new railways during the next two years at a cost of £30,000,000. The railway from Semi-palatinsk is to be extended to the Afghan frontier, and several new lines are to be built in Siberia.

Vickers (Aviation), Ltd., have received an order from the Irish Free State Department of Defence for a number of Vickers Vespa two-seater army co-operation aircraft, to be fitted with Armstrong-Siddeley Jaguar-geared engines. These machines will be for the use of the Irish Free State Air Force. The same type has been supplied to Bolivia, where it is necessary for aircraft to be operated at extreme altitudes.

The Egyptian State Railways have placed orders for 15,000 tons flat-bottomed rails with David Colville and Sons, Glasgow, and with P. and W. MacLellan, Glasgow, for the materials for Mallawi footbridge.

The Central Argentine Railways have placed an order with the Metropolitan Cammel Carriage, Wagon and Finance Co., Birmingham, for 2,060 goods wagons. The Birmingham Carriage and Wagon Co. have received an order from the same source for 351 steel bogie wagons. The total value of these orders reaches £600,000.

In connection with their Assuan Dam contract, Sir John Norton Griffiths and Co. have placed an order with Frank Butters and Co., Glasgow, for two 5-ton steam derrick cranes.

The Hydraulic Engineering Co., Ltd., Chester, have received an order from the Manchester Ship Canal Company for a large hydraulic accumulator for Latchford Locks.

Some Contracts—continued.

It is interesting to record that as a result of the satisfactory performance of land boilers supplied a few years ago for the boiler-house extensions at the Royal Dockyard, Devonport, Yarrow and Co., Scotstoun, Glasgow, have received an order for a fifth repeat unit, comprising Yarrow patent boiler, integral superheater, mechanical forced-draught stoker, and cast-iron economiser superimposed in series.

The London and North-Eastern Railway have placed contracts for 1,000 12-ton mineral wagons with the following firms:—S. J. Claye, Ltd., Long Eaton; W. H. Davis and Sons, Ltd., Mansfield; the Birmingham Railway Carriage and Wagon Co., Ltd., Smethwick; Hurst, Nelson and Co., Ltd., Motherwell; Chas. Roberts and Co., Ltd., Wakefield; Metropolitan Cammell Carriage, Wagon, and Finance Co., Ltd., London.

Three important Continental contracts have been secured by Riley Bros., Stockton. They comprise eight Riley's patent vertical boilers for the French Admiralty, twelve large marine boilers for the Glaverlsen Shipyard, Gothenburg, and five boilers of a similar type for Paulino Freres, Bilbao.

In connection with the scheme approved by the Glasgow Corporation for the reconstruction of the tramways power station at Pinkston, the Transport Committee of the Corporation have recommended the acceptance of the tender of John Thompson, Water-Tube Boilers, Ltd., Wolverhampton, for the installation of six boilers at the price of £90,327. Messrs. Thompson have also received an order from the Metropolitan Water Board for boiler plant for Deptford pumping station, to cost £26,945.

Edward Wood and Co., Ltd., Trafford Park, have been awarded a contract for the supply of steelwork in connection with the Manchester-Altrincham railway electrification scheme. The value of the order is about £50,000, and over 1,000 tons of steel will be required.

Mirrlees, Bickerton and Day, Ltd., Stockport, have recently received orders for Diesel engines from the Madras and Southern Mahratta Railway Co.; the Port Commissioners, Calcutta; India General Navigation and Railway Co.; Dabhoi Electricity Supply Co., Ltd.; Callender's Cable and Construction Co., Ltd.; City of Hamilton Waterworks; Rosthern Wynyard; town of Unity, Melford, Saskatchewan; Humboldt, and Panama Corporation.

An order for the supply of 16 Bristol-Jupiter series F engines has been placed by the Danish Military Air Force with the Bristol Aeroplane Co., Ltd. These engines are in addition to a number of Bristol-Jupiters supplied to the same Government earlier in the year.

Peter Lind and Co., Ltd., Westminster, have secured a contract from the London County Council in connection with the additional purification plant at the northern main drainage outfall, Beckton, at the cost of £78,913.

The Harland Engineering Company, Alloa, Scotland, have secured the order for the pumping plant in connection with the municipal water-supply scheme of the Hamilton Borough Council (N.Z.).

The Buenos Aires Pacific Railway have awarded a contract for points and crossings to the Isca Foundry Co., Ltd., Newport, Mon., and a similar order to T. Summerson and Son, Ltd., Darlington, to the total value of nearly £9,000.

The Auckland Transport Board has placed an order with R. Johnson and Nephew, Manchester, for trolley wire at the price of £1,370, and with the Enfield Cable Works, Ltd., for aerial cable at the price of £4,592.

The Hydraulic Engineering Co., Ltd., Chester, have been successful in obtaining an order from the Boston Dock and Harbour Commissioners for a hydraulic coal hoist, capstans, pumping plant, and accumulator for the port of Boston. It is expected that the contract will take about twelve months to complete.

SHIPBUILDING.

The Cie de Navigation d'Orbigny, Paris, have placed an order with Napier and Miller, Ltd., Old Kilpatrick, for a second general cargo steamer, 395 ft. long, 53 ft. broad, 35 ft. deep, of about 7,400 tons deadweight and 10½ knots speed. Triple-expansion reciprocating engines will be supplied by John G. Kincaid and Co., Ltd., Greenock. Napier and Miller have also obtained the sub-contract for the hulls of the two ferry-steamers ordered (as reported in *The Commercial*) from McKie and Baxter, Govan. It is also announced that the Govan shipyard of Harland and Wolff, Ltd., have received orders for two new high-class cargo vessels, one for the Nourse Line and one for the Hain Steamship Co., Ltd.

Contracts have been placed with Lithgows, Ltd., Port Glasgow, by Messrs. Westfal-Larsen and Co., Bergen, Norway, for two twin-screw oil-tankers, each of 13,500 tons dead weight. The vessels, which will be similar in size and type to two built at Amsterdam last year, will be propelled by Harland-B. and W. internal-combustion engines aggregating about 4,000 h.p.

A Continental shipowning concern have placed a contract with George Brown and Co., Greenock, for the building of a cargo steamer of 1,600 tons dead weight for service between London and the Continent.

New contracts for ships are still being secured on the North-East Coast, and the prospect for the earlier part of next year has been further improved.

It is understood that Sir W. G. Armstrong, Whitworth and Co., Ltd., Walker, have booked an order for another vessel for Norwegian owners.

The Cowpen Shipbuilding and Dry Dock Co., Ltd., Blyth, have secured a contract for a vessel for the Burnett Steamship Co., Newcastle, to be engined by the North-Eastern Marine Engineering Co., Ltd., Wallsend.

The Standard Oil Co., America, are reported to have placed an order for a 16,000 motor tanker with Palmers Shipbuilding Co., and a similar order with the Furness Shipbuilding Co.

Messrs. Short Bros., of Sunderland, are to build a cargo steamer for J. and C. Harrison, London.

Smith's Dock Co., North Shields, have booked orders for a 4,000-ton vessel for French owners, and a 6,700-ton cargo steamer for British owners.

The Furness Shipbuilding Co., Ltd., of Haverton Hill-on-Tees, are to place an order with William Gray and Co., Ltd., West Hartlepool, for a cargo vessel of about 8,000 tons, and the propelling machinery will be supplied by the Central Marine Engine Works of the builders. William Gray and Co. have also received a contract for the West Hartlepool Steam Navigation Company for a large cargo vessel, and will also supply the engines.

BOOKS RECEIVED.

"Crystal Analysis." By Sir William Bragg, K.B.E., D.Sc., F.R.S. Published by G. Bell and Sons, Ltd., York House, Portugal Street, London, W.C. 2. (12s. net.)

"Tungsten: A Treatise on its Metallurgy, Properties, and Application." By Colin J. Smithells, M.C., D.Sc. Published by Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C. 2. (21s. net.)

"Steel and its Treatment." By D. K. Bullens. Third edition, rewritten and reset. Published by John Wiley and Sons, New York; and Chapman and Hall, Ltd., London. (25s. net.)

"Pipe and Tube Bending and Jointing." By Stanley P. Marks, M.S.I.A. Published by Sir Isaac Pitman and Sons, Ltd., Parker Street, Kingsway, London, W.C. 2. (6s. net.)

"Chemical Plumbing and Lead-burning." By E. B. Partington, R.P., A.R.S.I. Published by Allen-Liversidge, Ltd., Westminster, S.W. 1. Price, 3s. 6d.

"A Handbook for Oxy-Acetylene Welders." By Leonard M. Fox, M.I.Mech.E. 2nd Edition. Published by Allen-Liversidge, Ltd., Westminster, S.W. 1. Price, 3s. 6d.

MARKET PRICES

ALUMINIUM.

99% Purity		—
Castings, 2.L5 Alloy	lb.	1/3–1/8
„ 2.L8 „	„	1/4–1/9
„ Silicon „	„	—

ANTIMONY.

English	£48	15	0
Chinese	31	5	0
Crude	20	0	0

BRASS.

Solid Drawn Tubes	lb.	12¾d.
Brazed Tubes	„	14¾d.
Rods	„	12¼d.
Wire	„	10⅞d.

COPPER.

Standard Cash	£68	17	6
Electrolytic	83	0	0
Best Selected	75	0	0
Tough	74	10	0
Sheets	110	0	0
Wire Bars	83	5	0
Ingot Bars	83	5	0
Solid Drawn Tubes	lb.	15d.	
Brazed Tubes	„	15d.	

FERRO ALLOYS.

Tungsten Metal Powder	lb.	£0	3	4½
Ferro Tungsten	„	0	3	1½
Ferro Chrome 4% to 60% carbon	unit	0	7	6
Ferro Chrome 6% to 8% carbon	„	0	6	6
Ferro Chrome 8% to 10% carbon	„	0	6	0
Ferro Chrome 1% carbon	„	0	15	0
Ferro Chrome Carbon Free	lb.	0	1	0
Metallic Chromium	„	0	2	6
Ferro-Vanadium	„	0	12	10
Ferro-Silicon 25%	ton	7	17	6
„ „ 50%	unit	0	5	0
„ „ 75%	„	0	7	0
„ Molybdenum 75%	lb.	0	4	2
„ Titanium	„	0	1	2
„ Nickel	£170–£175			
„ Cobalt	lb.	0	9	6
„ Manganese loose	12	10	0	
„ „ Export	13	0	0	
„ Phosphorus 25%	16	0	0	

FUELS.

Foundry Coke—			
S. Wales Export	£1	12	6
Sheffield „	1	4	0
Durham	1	5	0
Furnace Coke—			
Sheffield Export	1	4	0
S. Wales „	—		
Blast-Furnace Coke, at ovens	0	16	0

GUN METAL.

Commercial Ingots	£71	0	0

LEAD.

Soft Foreign	£21	6	3
English	22	15	0

MANUFACTURED IRON.

Scotland—			
Crown Bars	£10	15	0
N.E. Coast—			
Rivets	11	10	0
Best Bars	11	5	0
Common Bars	10	15	0
Lancashire—			
Crown Bars	10	15	0
Hoops	13	0	0
Midlands—			
Crown Bars	10	7	6
Marked Bars	12	10	0
Unmarked Bars	—		
Nut and Bolt Bars	9	2	6
Gas Strip	11	0	0
S. Yorks.—			
Best Bars	11	10	0
Hoops	12	0	0

PIG IRON.

Scotland—			
Hematite	£4	0	0
Foundry No. 1	3	18	6
„ No. 3	3	16	0
N.E. Coast—			
Hematite	3	18	6
Foundry No. 1	3	15	0
„ No. 3	3	12	6
„ No. 4	3	11	6
Cleveland—			
Foundry No. 3	3	12	6
„ No. 4	3	11	6
Silicon Iron	3	15	0
Forge No. 4	3	11	0
N.W. Coast—			
Hematite	4	9	6
Midlands—			
N. Staffs Forge No. 4	3	15	6
„ Foundry No. 3	3	19	6
Northants—			
Forge No. 4	3	11	0
Foundry No. 3	3	15	0
Derbyshire Forge	3	14	6
„ Foundry No. 3	3	18	6
West Coast Hematite	4	9	6
East „ „	4	7	6
Swedish Charcoal Pig	—		

PHOSPHOR BRONZE.

Rods	lb.	1/5
Tubes	„	1/9¼
Castings	„	1/4
Strip	„	1/4
Sheets 10 W.G.	„	1/5

SCRAP METAL.

Copper Clean	£63	0	0
„ Braziery	57	0	0
„ Wire	—		
Brass	43	0	0
Gun Metal	57	0	0
Zinc	14	0	0
Aluminium Cuttings	66	0	0
Lead	19	10	0

SCRAP METAL—continued.

Heavy Steel—			
S. Wales	3	10	0
Scotland	3	12	0
Cleveland	3	3	6
Cast Iron—			
Lancashire	—		
S. Wales	£2	19	6
Cleveland	3	5	0
Steel Turnings—			
Cleveland	2	16	6
Lancashire	—		
Cast Iron Borings—			
Cleveland	2	13	0
Scotland	2	14	0

SPELTER.

G.O.B. Official	—		
Hard	£17	5	0
English	20	7	6
India	18	10	0
Re-melted	19	5	0

STEEL.

Ship Plates (Scotland)	£8	12	6
„ „ (N.E Coast)	8	12	6
Boiler „ (Scotland)	10	0	0
„ „ (N.E. Coast)	10	0	0
„ „ (Midlands)	9	12	6
Sheets 20 W.G.	11	15	0
Angles (N.E. Coast)	8	2	6
„ (Midlands)	8	2	6
Joists	8	2	6
Heavy Rails	8	10	0
Fish-Plates	12	10	0
Light Rails	8	17	6
Sheffield—			
Siemens Acid Billets	9	10	0
Hard Basic	9	7	6
Medium Basic	7	17	6
Soft Basic	7	0	0
Hoops	10	0	0
Manchester—			
Hoops	9	0	0
Bridge and Tank Plates	8	17	6
Angles	10	5	0
Tool Steel, High Speed—			
Finished Bars 18% Tungsten	lb.	2/9	
Round and Squares	„	—	
Under ½ in.	„	3d.	
Round and Squares 3 in.	„	4d.	
Flats under 1 in. × ⅜ in.	„	3d.	
„ „ ½ in. × ¼ in.	„	1/–	

TIN.

Standard Cash	£176	10	0
English	178	10	0
Australian	180	5	0
Eastern	178	15	0
Tin Plates I.C. 20 × 14	box	19/–	
Block Tin Cash	£177	15	0

ZINC.

English Sheets	£29	10	0
Rods	33	0	0
Battery Plates	27	0	0

METAL MARKET REPORTS.

The position in regard to copper has not changed for the better, and there has been no improvement to record in the demand for electro. The lack of any announcement of a definite programme in regard to tin has created disappointment and resulted in a decline in values. The moderate volume of home trade business in lead has not been sufficient to rally prices materially. In regard to spelter the outlook is obscure, pending a decision as to the future of the European Cartel. Business has been on a restricted scale.

Forward buying of pig iron is still scarce, and makers are becoming somewhat apprehensive. At the moment, most furnaces are well placed with orders, but the uncertain outlook in the coal trade is adverse to improving conditions. Steel makers are carrying on quietly, but the heavy industries in particular need business. Export demand is poor, the bulk of the orders coming from the home shipyards and structural and engineering industries.

The market in tinplates has been much under the influence of that of tin. The makers are, however, in a strong position, some having sold their quota up till March, while others have bookings even further ahead. The general outlook is quite favourable. In regard to galvanized sheets, it appeared that the market was on the way to recovery, but after some spasmodic buying on the part of important users abroad, it has relapsed into a dull state. Prices are inclined to be irregular. Although the market in quicksilver has not been very active, the tone has been fairly good. Material on spot is quoted at around £23 per bottle.